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Students Using Cochlear Implants in Inclusive Environment: The Process of Editing and Revising Written Products

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Abstract

Written expressions encompass putting events, emotions, and thoughts on paper with the written symbols of a language in compliance with its rules. Even with cochlear implants, students with hearing loss who experience delays in language and academic skills face various difficulties in written expression skills. Editing and revising studies, which play an important role in the writing process in coping with these difficulties, serve to increase the quality of written products and to allow students to independently edit and review their writing. This study aims to examine the editing and revising processes of the written products by students with cochlear implant in an inclusive environment. This case study was conducted with two secondary school students with cochlear implant. Research data was collected through observations, interviews, validity and reliability committee meetings, process products, documents, materials used in the preliminary stages, written expression skills assessment forms, and writing revising taxonomy. At the end of the study, it was observed that students needed corrections such as adding, deleting, substituting and rearranging sounds/syllables/words in their written products, that these corrections were made in suffixes and sentences as units, and that students needed various auditory and visual clues while revising their writings. Based on the research findings, it was concluded that the students with cochlear implants who participated in the study benefited from the process of editing and revising their written products and that the experiences gained in the process contributed to the quality of the written products.

Keywords:

Cochlear Implant; Editing and Revising Process; Inclusive Environment; Students With Hearing Loss; Writing Process

Introduction

Students with hearing loss tend to experience delays in language skills development compared to their hearing counterparts. Early intervention, along with cochlear implant, which have a positive impact on oral language skills development, plays an important role in the mitigation of this delay. These improvements in oral language skills have led to the placement of students with hearing loss in inclusive environments and the expectation that they will be able to perform close to their hearing peers in

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reading and writing skills. However, existing literature underlines that the increased intelligibility of speech and improved listening skills that cochlear implant offer do not guarantee academic success, and students with hearing loss in inclusive environments still lag behind their hearing peers in literacy skills and that they require support education (Akay, 2023; Arfe et al., 2016; Mayer et al., 2016; Wolbers, 2008; Yaşamsal et al., 2013). This study determines the areas that require correction in the written products of such students and examines the editing and revising processes to support their development of written expression.

Writing is a means of communication where individuals use symbols within the rules of a language to express their emotions, thoughts and experiences. Educational programs aim to incorporate writing skills because written expression plays a significant role in academic success and correlates greatly with listening, speaking, and reading skills while also contributing to the development of other skills (Arfe et al., 2016). It follows that a systematic approach that accommodates the development of writing skills is strongly advised in educational environments and that this approach carries significance in the improvement of linguistic, academic, and social skills of students with hearing loss just as with students with typical development (Dostal & Wolbers, 2014; Dunn et al., 2022). The writing process consists of stages starting from selecting the topic that constitutes the content of the text, drafting, writing the content, editing and revising the text and publishing it (Kolb et al., 2013). These stages not only support the development and organization of content and opinions but also contribute to the formation of syntactically accurate sentences, accurate spelling, correct use of vocabulary in context, full and correct spelling of suffixes, correct use of punctuation and rules of the language which altogether determine the quality of the written product (Dunn et al., 2022; Grenner et al., 2022; Kolb et al., 2013). After drafting the text, comes the editing and revising stages, which allow the integration or removal of opinions, self-revision and redrafting (Dostal & Wolbers, 2014). Students with typical development who are more competent in language skills are able to identify and act on problem areas such as sentence structure, vocabulary use and spelling as areas that affect the quality of the text and need changing in the editing and revising stages. However, for students with hearing loss, who lag in their linguistic and academic skills, the production of a written text and the editing and revising of the text is a challenging task (Dostal & Wolbers, 2014; Dunn et al., 2022). Therefore, working on the written product gives the student the opportunity to rearrange the content of the writing and correct errors in letter-sound relationships, syntax, semantic and pragmatic in his/her own writing under the guidance of the teacher (Grenner et al., 2022; Karasu, 2014).

Research focusing on the writing skills of students with hearing loss compare the performance of these students with their hearing counterparts, examine the development of the written products for various age groups, assess reading comprehension and written expression skills and the impact of early implants in writing skills (e.g. Antia et al., 2005; Arfe et al., 2016; Bell et al., 2019; Çizmeci & Çiprut, 2018; Efe & Karasu, 2017; Geers & Hayes, 2011; Oliveira et al., 2020; Quick et al., 2018; Yaşamsal et al., 2013). However, there has been no research on the writing process of students with hearing loss on the national level and international literature is also limited in this area. One of the few international studies in the area focuses on the editing and revising process of the written products of students with cochlear implant (Aberth & Warfel, 2021) while the others study the efficiency of writing processes and interactive writing studies (Bajarh, 2019; Milaham, 2020; Wolbers, 2008). Aberth and Warfel (2021) study the contribution of a program on self-regulatory strategies on the writing skills of a student with cochlear implant. They determine that interventions toward self-regulation offer important benefits in the revision of the written product and potentially improve writing skills as well as reading comprehension skills. Research on interactive writing (Wolbers, 2008) underlines that students benefit from the practice at the word-definition level at primary school and the reorganization and revision level at secondary school. Similarly, Bajarh (2019) highlights that a balanced and interactive writing task reinforces writing skills significantly. Miliham's study (2020), on the contribution of the writing process to the writing skills of students with hearing loss, finds that students benefit from their experience in creating written products and that they use the stories shared in the process to create their own content. An examination of the results of these studies reveals that the writing process makes a significant contribution to the written products of students with hearing loss. However, there is still a need for research to clarify the areas where students with cochlear implant make mistakes and how the editing and revising processes can be applied. The present study can be useful in determining the areas where students with hearing loss require help and developing support education plans to help them. Moreover, this study may offer insights into the difficulties that students with cochlear implant experience in writing tasks in inclusive environments and the benefits of editing and revising processes in the writing process.

This study aims to examine the editing and revising processes of the written products of students with cochlear implant in inclusive environments. With these in mind, the study aims to answer questions such as (a) What kind of corrections have been made to the students' written products? (b) How were the editing and revising processes carried out? (c) How

did the students' performance in writing improve in the process?

Methodology

Research Design

This study used a qualitative case study design. A case study is a research design that aims to examine events, situations, individuals, environments or processes in depth on the basis of 'how' and 'why' questions (Yin, 2014). Case studies can be classified according to their purpose and the units of analysis. This research is a holistic single case study because of the determination of a single analysis unit in which the stage of reviewing and revising the written products of two students with cochlear implant is covered, and a descriptive case study as it intends to describe in detail the process of reviewing and revising written products.

Participants

The participants of the study are two students with cochlear implant who are in an inclusive environment, a researcher, parents of the students, a Turkish Language teacher and members of the validity committee.

Students have been chosen through criterion sampling as in purposive sampling methods. These criteria are as follows: students should be in inclusive educational environments, students should not have accompanying inadequacies besides hearing loss, students use cochlear implant, students should be in the fourth grade or later grades as free writing studies to improve writing skills start at this level (Ministry of National Education [MEB], 2020). Two students who met these criteria were included in the study. The demographic, audiological and educational background of the participants is shown in Table 1.

Table 1
Demographic, audiological and educational background of the students

Students		Beyza	Yunus
Grade		6	6
Calendar age		11;6	12;1
Hearing aids	Right	CI*	--
	Left	HA**	CI
CI age (years, months)		1;5	1;9
Hearing aid use before CI (months)		6	3
CI use (months)		122	124
Beginning of inclusive education		4;2	3;9

*CI: Cochlear Implant
**HA: Hearing Aids

As seen in Table 1, both participants are in secondary school and started using hearing devices at an early age. In the meetings with the parents, it was found that Beyza used her hearing device and the cochlear implant actively and without breaks whereas Yunus used it only in intervals as the device frequently broke down.

Yunus and Beyza are in different classes in the same school and their teacher has 17 years of experience in her job. The teacher has not received in-service training on the education of children with special needs. Beyza's parents are primary school graduates. The mother is a housewife, and the father is a worker. Two of Beyza's six siblings are hearing impaired. Yunus's mother is a primary school graduate and a housewife, and his father is a secondary school graduate who is a laboratory technician. Yunus has one other sibling who is also hearing impaired. Both children's parents have said that they communicate verbally at home with all of their children.

The researcher graduated from Audiometry in 2015 and the Department of Teaching of the Hearing Impaired in 2019. She has been working as a special education teacher at a primary school affiliated with the Ministry of Education since 2020. The committee consisted of two specialists with 26 and 28 years of experience in assessment and qualitative research in the field of the development of literacy in students with hearing loss.

Data Collection Techniques and Tools

Case studies require multiple data sources to attain reliability and validity (Yin, 2014). In order to thoroughly examine the editing and revising processes of the written products, the researcher used (a) observations, (b) interviews, (c) validity committee meetings and reports, (d) process products, (e) documents, (f) materials used in the preliminary stages of writing, (g) written expression skill assessment form and (h) taxonomy of revising written product.

a. Observations that provide researchers with first-hand information can be conducted directly or as participant observers. Since the researcher conducted the editing and revising processes herself, she acted as a participant observer. In addition, video recordings of the preliminary preparation work, the writing process of the written product, and the editing and revising processes were taken in order to monitor the preliminary stages, to ensure that the editing and revising processes are carried out as planned, to control the practitioner's compliance with certain rules during the writing process and correcting the student's writing, and to perform reliability checks.

b. Semi-structured interviews before, while and after the study conducted with the parents and the teacher were also recorded on audio. In these interviews, the teacher was asked for her opinions on the students' attitude toward writing tasks and the writing process, while the parents were asked questions about the students' use and production of written materials.

c. During the entire research process, the materials and application plans used in the preliminary preparation study were examined at the 14 validity meetings held regularly every week, video recordings of the preliminary preparation study, writing phase and editing and revising applications were watched, interview transcripts and scores of written products were checked.

d. Process products consist of written products obtained after the writing process with the plans containing the applications in the editing and revising processes with the preliminary preparation. The plan used in the preliminary study consists of an introductory sentence explaining the application, questions to be asked about the material, and possible situations for student participation during the application. Stages in the editing and revising processes have been chosen to meet the student's needs for word or sentence-level correction. Written products were obtained by asking the participants to write a story after the preliminary stage.

e. Documents in the research include the Student Information Forms which show the audiological, demographical and educational background of the students, and hospital files including their audiograms, their age when they started using cochlear implant and information about their hearing devices.

f. Preliminary studies enable students to recycle their knowledge and experience, and facilitate the use of language for a variety of functions. The researcher in this study shared single and sequential cards with the students and explained the story before asking them to write their version. Six single and six sequential cards were used in odd and even weeks throughout the study.

g. The written expression skill assessment form, whose validity as an evaluation tool has been confirmed in advance, consists of four main parts: the title, the order of expression, the richness of expression and compliance with the rules of writing. Out of a hundred points, each part is assigned 3, 51, 24 and 22 points respectively (Çizmeci & Çiprut, 2018; Efe & Karasu, 2017).

h. Taxonomy of revising written product is used to monitor the editing and revising processes to evaluate the written products of the students. Originally developed by Faigley and Witte (1981), the taxonomy was later expanded by Crawford et al. (2008) and then adapted by Karasu (2014) to be used in the assessment of the written products of students with hearing loss. It enables the researcher to examine the units that require correction and determine the type of correction in writing assessment. The type of correction encompasses various levels such as sound, syllable, and suffix changes, as well as additions or omissions to and from words, replacement of words, reorganization, rules of writing, merging and expanding. The units of correction include sounds, syllables, suffixes, words, clauses, sentences, multiple sentences, paragraphs and punctuation marks. As for the type of correction, the researcher checks the extent to which the student performs self-revision without assistance, and with visual or verbal clues.

Research Environment

The research has been conducted at a state school affiliated with the Ministry of National Education in a separate class allocated to this study by the school administration. In one-on-one sessions, the researcher sat on the side of the student's ear with the cochlear implant. All sessions were carried out with the teacher's guidance not to disrupt the regular schooling program of the students.

Role of the Researcher

The researcher assumed a participant observer role in line with the objectives of the qualitative research (Yin, 2014). Thereby, the researcher carried out needs analysis, collected, analyzed and interpreted the data. In the process of obtaining, reviewing and correcting the written product, the researcher prepared the materials to be used in the preliminary writing stage, planned and implemented the tasks and evaluated the products.

Data Collection Process

The data has been collected over a twelve-week period in the 2022-2023 academic year. After the participants were determined, the researcher met with the teacher and the parents, and carried out the one-on-one sessions with the students on separate days. At the opening stage, the researcher shared the designated card of the week after an introduction. Then the student was asked to tell the story following questions on the main theme encouraging their contribution. Finally, the student was asked to write a story on the events that were laid out. There were no interventions or any time limits set for the task. On finishing the story, the student was asked to revise what he/she had written and make any corrections they wanted. Upon completion of self-revision and revising, the student and the teacher moved on to review and correct the text together. The preliminary study, the writing stage and the editing and revising stages were carried out on the same day. Editing and revising stages took 10-20 minutes with Yunus and 14-19 minutes with Beyza.

Trustworthiness

In order to ensure trustworthiness, data has been collected longitudinally, systematically and thoroughly, and all the materials in the preliminary stage, plans and the pre-writing stages, the editing and revising stages and the grades for the written product have been checked on a weekly basis by the reliability committee. The content validity of the questions asked

during the interviews with the parents and the teacher has been verified by a field expert who works with students with hearing loss. The voice recordings have been transcribed and the transcriptions have been confirmed by the interviewees. For dependability, 50% of the written products were scored by a field expert with 25 years of experience with students with hearing loss, and 98% agreement was achieved. For confirmability purposes, 50% of the editing and revising applications for both students were monitored by the field expert, and it was confirmed that the applications were carried out as planned.

Data Analysis

Data can be analysed during data collection, descriptively or by content analysis in case studies (Yin, 2014). Data in this research has been analyzed descriptively. Based on the research objective and research questions, the types of errors in students' products, the units of error and types of correction have been described within the framework of the revising taxonomy, while improvements in the written expression grades have been described according to features checked in the evaluation process.

Research Ethics

This study has been approved by the ethics committee of the university (22.11.2022/440804) and was granted a research permit by the Ministry of Education (20.12.2022/E-45468433). The families and the teacher gave their written consent to participate in the study. Research findings were shared on demand with the families and the teacher, and the students were given aliases.

Results

Research findings are given below. What kind of corrections have been made? During the analysis, the products have been examined under (a) the type of correction and (b) the unit of correction as determined by the taxonomy.

a. Type of correction: Types of error correction for the written products are shown in Table 2.

Table 2 shows that the types of errors in Beyza and Yunus' written products are different and therefore they need different types of correction. Beyza needed corrections in the types of deletion, substitution and addition of sounds/syllables/fixes or words. With Yunus, corrections in the types of reorganization and expansion were made. This finding shows that Beyza can organize the content of the writing, narrate the events in a certain order and express her thoughts in writing within the framework of the rules of the language, while Yunus needs more support in creating the content of the writing, organizing his thoughts and using the language. Another striking finding is that Beyza needs corrections in the types of addition of sounds/syllables/fixes or words more than other types of correction. Students with hearing loss who experience delays in language skills reflect their use in the spoken language in the use of some elements that make up the syntax of the language and may need corrections in the type of addition within the sentence. The high number of errors in Yunus' written expressions regarding letter-sound relationships, syntax, semantic and pragmatic has created a need for correction in the form of reorganization and expansion in his writings.

Table 2

Types of correction

	Sound/syllable/ suffix or Word Deletion				Substitution a sound/syllable or word				Adding a sound/ syllable/suffix or word				Reorganization				Spelling Rules				Combining				Expansion			
	Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus	
Weeks	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%
1	-	-	-	-	1	14.29	-	-	6	85.71	-	-	-	-	4	100	-	-	-	-	-	-	-	-	-	-	-	-
2	7	30.43	-	-	2	8.70	-	-	9	39.13	-	-	-	-	6	63.64	5	21.74	1	9.09	-	-	-	-	-	-	3	27.27
3	3	14.29	-	-	2	9.52	-	-	15	71.43	-	-	-	-	9	69.23	1	4.76	-	-	-	-	-	-	-	-	3	30.77
4	7	26.92	-	-	2	7.69	-	-	14	53.85	-	-	-	-	5	71.43	3	11.54	-	-	-	-	-	-	-	-	2	28.57
5	4	22.22	-	-	3	16.67	-	-	5	27.78	-	-	-	-	11	68.75	6	33.33	-	-	-	-	-	-	-	-	5	31.25
6	5	20.83	-	-	6	25.00	-	-	9	37.50	-	-	-	-	7	70.00	4	16.67	1	10.00	-	-	-	-	-	-	2	20.00
7	2	20.00	-	-	1	10.00	-	-	3	30.00	-	-	2	20.00	7	33.33	2	20.00	8	38.10	-	-	-	-	-	-	6	28.57
8	1	5.55	-	-	-	-	-	-	14	77.78	-	-	-	-	6	66.67	3	16.67	-	-	-	-	-	-	-	-	3	33.33
9	7	25.92	-	-	-	-	-	-	10	37.04	-	-	-	-	9	69.23	10	37.04	-	-	-	-	-	-	-	-	4	30.77
10	2	6.06	-	-	7	21.21	-	-	15	45.45	-	-	-	-	15	75.00	8	24.24	2	10.00	1	3.04	-	-	-	-	3	15.00
11	1	3.85	-	-	4	15.38	-	-	12	46.15	-	-	-	-	12	54.55	9	34.62	4	18.18	-	-	-	-	-	-	6	27.27
12	2	8.33	-	-	3	12.50	-	-	17	70.84	-	-	-	-	10	76.92	2	8.33	1	7.69	-	-	-	-	-	-	2	15.39

b. Unit of Correction: According to the taxonomy the units of correction were sound, syllable, suffix, clause, sentence, multiple sentences, paragraph and punctuation. Units of correction on the students' written product in this assessment are shown in Table 3.

In the units where the error was corrected, it is seen that Beyza needs more additional corrections along with sound/syllable and word corrections (Table 3). In Turkish, each addition to a word has the feature of changing the meaning. This feature affects the meaning of the word as well as the syntax accuracy of the sentence. This finding, consistent with the findings obtained in the type of error correction (Table 2), shows that Beyza needs more support in using the morphological elements of the language. Since Yunus had difficulty in creating the content in his written products, needed to reorganization the writing and expand the content, each sentence in the units where the error was corrected had to be corrected. In the use of punctuation marks, which constitute the mechanical element of writing, it is seen that the use of punctuation marks became more necessary with the enrichment of the content in Beyza's written products, and Yunus started to use punctuation marks in the last week of the practices.

How was the editing and revising process carried out?

In the one-on-one sessions carried out with both students throughout the written product evaluation process, the correction technique in the 'written product evaluation taxonomy' has been detailed on a weekly basis as follows (Table 4).

In terms of error correction methods, it is seen that both students need the teacher's guidance at different levels (Table 4). While Beyza needed written cues to correct her errors in the first weeks, the frequency of noticing her errors and correcting them without assistance increased in the following weeks. This finding shows that editing and revising activities carried out in a one-on-one environment under the guidance of the teacher increased the student's awareness of the morphology, semantics, syntax and

Table 3

Unit of correction

	Sound/Syllable Correction				Suffix Correction				Word Correction				Sentence Correction		Clauses Multiple Sentences Paragraph Correction				Punctuation			
	Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus	
Week	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%
1	1	14.29	-	-	6	85.71	-	-	-	-	-	-	4	100	-	-	-	-	-	-	-	-	-	-
2	2	8.69	-	-	6	26.09	-	-	9	39.13	-	-	6	100	-	-	-	-	6	26.09	-	-
3	9	45.00	-	-	9	45.00	-	-	1	5.00	-	-	8	100	-	-	-	-	1	5.00	-	-
4	6	26.09	-	-	11	47.83	-	-	3	13.04	-	-	9	100	-	-	-	-	3	13.04	-	-
5	1	8.33	-	-	5	41.67	-	-	4	33.33	-	-	8	100	-	-	-	-	2	16.67	-	-
6	6	30.00	-	-	5	25.00	-	-	4	20.00	-	-	6	100	-	-	-	-	5	25.00	-	-
7	2	22.22	-	-	4	44.44	-	-	2	22.22	-	-	7	75.00	-	-	-	-	1	11.12	1	25.00
8	3	17.65	-	-	4	23.52	-	-	3	17.65	-	-	6	100	-	-	-	-	7	41.18	-	-
9	4	22.22	-	-	4	22.22	-	-	6	33.34	-	-	8	100	-	-	-	-	4	22.22	-	-
10	3	12.00	-	-	9	36.00	-	-	8	32.00	-	-	14	100	-	-	-	-	5	20.00	-	-
11	1	5.00	-	-	10	50.00	-	-	3	15.00	-	-	12	42.86	-	-	-	-	6	30.00	4	57.14
12	2	9.09	-	-	11	50.00	-	-	5	22.73	-	-	10	100	-	-	-	-	4	18.18	-	-

Table 4

How the mistake is corrected

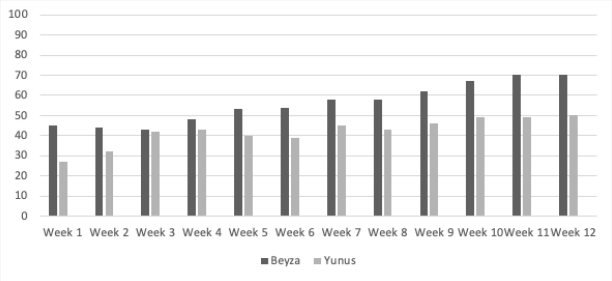
	Identifying the Mistake and Correcting It Without Assistance				Self-Revision When the Mistake is Pointed Out				Revision Through Explanation				Revision by Looking at the Corrected Version			
	Beyza		Yunus		Beyza		Yunus		Beyza		Yunus		Beyza		Yunus	
Week	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%	Correction	%
1	3	42.85	-	-	1	14.29	-	-	1	14.29	-	-	2	28.57	4	100
2	15	65.21	-	-	-	-	-	-	6	26.09	-	-	2	8.70	6	100
3	3	14.29	-	-	2	9.52	-	-	9	42.86	-	-	7	33.33	8	100
4	15	57.69	-	-	2	7.69	-	-	7	26.93	-	-	2	7.69	9	100
5	5	27.78	-	-	2	11.11	-	-	7	38.89	-	-	4	22.22	8	100
6	10	41.66	-	-	4	16.67	-	-	6	25.00	-	-	4	16.67	6	100
7	2	20.00	-	-	4	40.00	-	-	4	40.00	-	-	-	-	7	100
8	6	33.33	-	-	5	27.78	-	-	7	38.89	-	-	-	-	6	100
9	16	59.26	-	-	2	7.41	-	-	7	25.92	-	-	2	7.41	8	100
10	12	36.36	-	-	3	9.09	-	-	14	42.42	-	-	4	12.13	14	100
11	9	34.61	-	-	6	23.08	-	-	11	42.31	-	-	-	-	12	100
12	10	41.67	-	-	4	16.66	-	-	10	41.67	-	-	-	-	10	100

pragmatic of the language. Yunus, on the other hand, needed the teacher's guidance and written cues in all written products. This situation can be explained by the fact that Yunus needs support not only for editing and revising of written products but also for the development of his oral language skills, which form the basis of reading and writing skills.

How did the students improve in their written expression performance?

The written products obtained throughout the semester have been assessed according to the Written Expression Skill Assessment Form. Total scores of both students for written expression skills are shown in Graph 1.

Graph 1.
Total written expression score



Graph 1 shows that Beyza scored lower than 50 in the first four weeks and then her grades in written expression improved. In the interview dated 15.02.2023, the parents were asked if Beyza asked for help in her writing assignments, to which the father replied, "I think she asks for help to form sentences" and the mother replied "Sometimes she thinks she made a mistake and wants help to check the spelling of the words" (15.02.2023, Interview Record 4'44''). In the last interview dated 30.05.2023, the parents were asked if they saw any progress in their daughter's written expression skills and if they did, what they were. The parents replied, "Of course, we do. She used to make a lot of mistakes in the use of suffixes. She can now use them correctly. Even while speaking she would omit suffixes. She uses the suffixes more accurately in her speech now (30.05.2023, Interview Record 2'05''). In the first meeting with the teacher, dated 16.02.2023, the teacher was asked "What can you say about the written expression performance of your students with hearing loss?" She answered with reference to their motor skills in writing and said "They write beautifully. They care for their writing more than normal students." When the question was rephrased as "What do you think of their performance in terms of story or essay writing?" She responded with reference to the length of the texts they produced and said "... Beyza can write half a page on a large-size notebook (16.03.2023 Interview Record 3'45''). In the last interview dated 31.05.2023, she replied to the question "Do you see any improvement in Beyza's writing expression skills?" as "I can say that she is more confident now. She is more willing to participate in the writing tasks in class now. I believe she has greater confidence in herself" (31.05.2023, Interview Record 3'40'').

In the interview dated 15.02.2023, Yunus's mother was asked her opinions on his written expression skills, to which she replied, "He doesn't like writing because he cannot form sentences. I help him by dictating words syllable by syllable. I correct his sentences so that he can put them in his writing. He has a very limited vocabulary range. He can only write the words he has memorized (15.02.2023, Interview Record 4'20''). The last interview dated 01.06.2023 was conducted with Yunus's father. The father was asked "Do you see any improvement in Yunus' written expression skills? If so, what are they?" And the father replied, "There is a world of differences between the beginning of the semester and now. He can now put the events he sees into writing. He can write words more accurately. And he is more willing to tell us about things (01.06.2023, Interview Record 1'36''). In the first interview with the teacher, dated 16.02.2023, the teacher said she could not do writing tasks with Yunus and when she dictated words, Yunus was unable to write them accurately. In a later interview dated 31.05.2023, the teacher acknowledged that "Yunus's written expression improved greatly in terms of content. He still has a lot of work to do in terms of the rules of writing. He tends to misspell certain words and suffixes. Still, he is more willing to write compared to the past" (31.05.2023, Interview Record 2'40'').

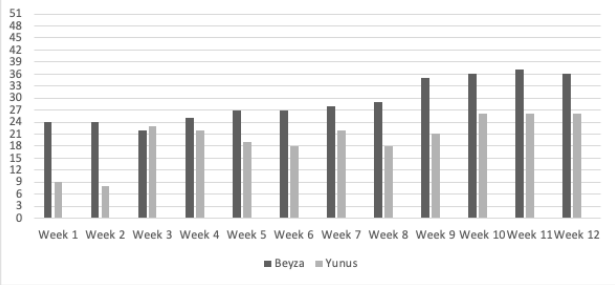
The total written expression score consists of the points taken from the sections (a) title, (b) narrative layout, (c) narrative richness and (d) compliance with spelling rules. In order to determine the students' strengths and weaknesses in written expression, their performances in these departments were examined during the intervention process and the findings are presented below.

a) Title: There were no titles in Beyza's writings in the first and third weeks. In Weeks 2, 4, and 9, Beyza used titles in her writing, but the titles were irrelevant to the topic. In the remaining weeks, Beyza managed to use titles that were directly related to her topics in writing. As for Yunus, he had a title for all his writings except for that of Week 1. He used a title for all his texts but failed to connect the title with the topic in the first five weeks. Yunus managed to put a relevant title that covered the topic of all his writings in the remaining weeks.

b) The Order of Expression: Another feature in the Written Expression Skill Evaluation Form is the narrative layout. Evaluated over 51 points in the evaluation form, the narrative layout consists of three parts: introduction, development and conclusion. Students' scores in the narrative layout section are presented in

Graph 2.

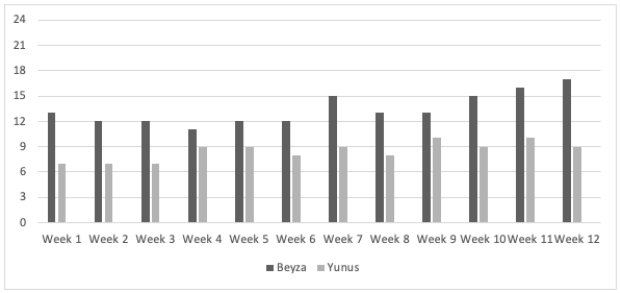
Graph 2.
Narrative layout points



As can be seen in Graph 2, Beyza received the lowest score from the written product obtained in the third week and the highest score in the eleventh week in the narrative order. It is observed that Beyza has an introductory paragraph in all her products except the third week. She received 2/5 points in the first three weeks for the clear presentation of the subject by explaining the subject and the main idea. In the eleventh and twelfth weeks, she achieved the highest score in the evaluation process in this feature by receiving 4 points from these features. It was seen that she did not write a paragraph for the development section for the first four weeks, but wrote one in accordance with the flow of events and context from the fifth week onwards. In the narrative layout, the ability to 'present the subject/main idea clearly' is evaluated over 10 points. Beyza received 4 points from this feature until the sixth week, and she received 8 points from the written product obtained in the last week. As for the conclusion section, it was seen that she did not write a conclusion paragraph until the fifth practice, and although she intended to write the paragraph in structure in the following weeks, she had difficulty bringing the events to a conclusion in terms of content. In Yunus's written products, it was seen that the first two weeks' scores were significantly lower in the narrative layout section compared to other weeks. Examination of the products showed that Yunus could not score in the part on 'the presence of subordinate ideas that support the main thought' and 'writing events, feelings and thoughts with logical consistency and sequence' in this section. Yunus tried to write on the topics for the first two weeks in a few sentences mentioning a single event in short sentences.

c) The richness of expression: Another feature in the written expression skill evaluation form is the richness of expression. The richness of expression, evaluated over 24 points in the evaluation form, assesses the accuracy in writing and using words correctly and in place, the accuracy of sentences and avoiding word repetition in explaining thoughts. The scores related to the richness of expression in the written products of the students are presented in Graph 3.

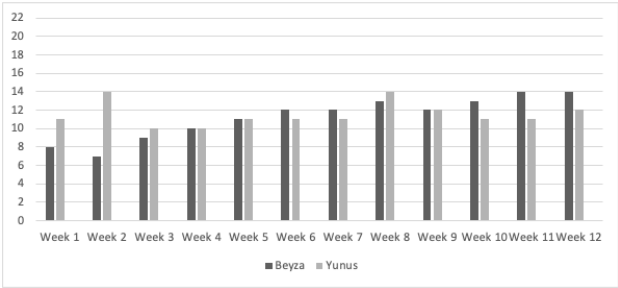
Graph 3.
Narrative richness scores



As can be seen in Graph 3, Beyza received the lowest score in the narrative richness section from the written product obtained in the fourth week. In this written product, it has been observed that Beyza has difficulty in spelling words and syntax of sentences. Yunus, on the other hand, received the lowest score in the narrative richness section from the written products obtained in the first three weeks. It is observed that Yunus has difficulty using suffixes according to syntax in his writings, makes mistakes in spelling words and tends to use the same words repetitively.

d) Compliance with the spelling rules: In the section on compliance with spelling rules evaluated over 22 points in the evaluation form, the layout, the legibility of the writing, the correct use of punctuation marks, the accuracy of upper and lowercase letter usage and paragraph layout characteristics are scored. The scores in the section on compliance with the spelling rules in the written products of the students are presented in Chart 4.

Graph 4.
Scores for compliance with spelling rules



As seen in Graph 4, Beyza received the lowest score from the written product of the second week and the highest score from the written products obtained in the eleventh and twelfth weeks from the spelling compliance section. The 'correct use of punctuation marks' which is important in compliance with spelling rules, is evaluated over 10 points. Beyza received the lowest score from this feature in the first and second weeks, and the highest score in the eleventh and twelfth weeks with 5 points. It has been observed that Beyza puts a period at the end of each sentence in her written products, but has difficulty using commas,

speech lines and quotation marks. On the other hand, Yunus received the lowest score from the written products in the third and fourth weeks and the highest score in the second and eighth weeks in compliance with the spelling rules. It has been observed that Yunus does not put a period to the end of some sentences, the use of commas is limited, and he does not use punctuation marks other than these two.

Conclusion

This research aims to delve into the editing and revising processes of the written products of two students with cochlear implant in an inclusive education environment. An examination of the revising process reveals that both students make similar mistakes except for the components which focus on syntax accuracy and error correction. In Beyza's case, the corrections required were often at the sound, syllable, suffix and word levels, whereas Yunus seemed to require sentence-level corrections in the entire text. It seems that this diversity in the type and number of errors in the written products of these students who had cochlear implant in the early stages of life and were in the same educational environment is reflected in their performance in organizing their thoughts, determining relationships between events, and expressing their thoughts in syntax-correct sentences. Although the type and unit of correction that the two students need assistance with are different, these findings are parallel to other research findings in that students with hearing loss have difficulty in editing the content of the product, the accuracy of sentences, the richness of expression and compliance with spelling rules (e.g. Bajarh, 2019; Grenner et al., 2022; Mayer, et al., 2016; Milaham, 2020; Straley et al, 2016; Yaşamsal et al., 2013).

Various studies state that one area where students with hearing loss need the greatest assistance is the use of derivatives and inflections (Antia et al., 2005; Bajarh, 2019; Karasu, 2014). Derivatives and inflections along with syntax accuracy directly affect the accuracy of the expression. These findings demonstrate that Beyza needs more correction in the suffixes related to tenses and in suffixes related to orientation, while Yunus has difficulty forming sentences by juxtaposing words with suffixes in accordance with the syntax. Based on the results of other studies and current research findings, it can be said that there may be various units that need correction in the written products of students with hearing loss due to the delay experienced in the acquisition of other language skills. Their individual differences, in other words, audiological, linguistic and educational backgrounds affect the type and units of errors.

Another finding of the current study is that, similar to other research findings, students did not have difficulty spelling words they frequently use in daily life. However, students were able to use words they did not encounter frequently when sharing events verbally, but they had difficulty with both spelling and syntax in written expression (Antia et al., 2005; Quinck et al., 2019; Straley et al., 2016). Pre-writing studies play a significant role in overcoming these challenges as well as difficulties concerning written expression skills such as creating the content, organizing ideas, logical flow and sequencing events, and accuracy of syntax and word choice (Crosson & Geers, 2001). Researchers in this study used sequential and single cards demonstrating the content in the pre-writing studies. When the written products are examined, it could be observed that students benefited from the stories used in the preparation stage and were able to create the content of the products as also suggested by the research results of Miliham (2020). Assigning writing tasks without pre-writing studies may cause students with hearing loss, who experience delays in language skills, to have difficulty in various elements of written expression, and creating content, which may hinder their actual performance in written expression (Crosson & Geers, 2001). Therefore, audio-visual aids such as story books, sequential cards, single cards, photos, films, and documentaries that can enable the demonstration of the experience can be used in the pre-writing stages in order to determine the actual strengths and weaknesses of students in written expression (Crosson & Geers, 2001; Grenner et al., 2022).

It was observed, at the end of 12 weeks that students showed improvement in the title, narrative layout, narrative richness and compliance with spelling rules along with the total written expression score thanks to the practices employed in pre-writing. These findings are similar to other research findings in which various educational applications were made for the development of written expression skills of students with hearing loss (Aberth & Werfel, 2021; Bajarh, 2019; Wolbers, 2008). Bajarh (2019) emphasizes in his research on students with hearing loss that interactive writing activities have a positive impact on writing skills. Similarly, in the research conducted by Wolbers (2008) on balanced and interactive writing courses, it was concluded that his students significantly improved in editing and revising their writing.

The main purpose of the process of reviewing and correcting the written product is to increase the quality of the product. Editing and revising written products also play an important role in the process of these students becoming independent writers (Kolb et al., 2013). The applications listed in the 'error correction method' section in the taxonomy of writing revision of this paper include the stages starting from the student's self-identification of the error and correction with minimum help, leading to correction by reviewing. When the applications were examined, it was seen that Beyza had difficulty noticing and

correcting her mistakes at the beginning of the process, but during the process, she was able to find and correct her mistakes on her own without the help of the teacher. This finding is consistent with the results of the research emphasizing that the process of reviewing and correcting written products allows students with hearing loss to notice their mistakes and correct their mistakes by using clues about letter-sound relationships, syntax, meaning and usage (Aberth and Werfel, 2021; Bajarh, 2019; Grenner et al., 2022; Karasu, 2014). When the applications carried out with Yunus, the other participant of the study, were examined, it was seen that the student had difficulty in noticing his mistakes and correcting them without help due to the high number of syntax errors and the need to reorganization the content of the writing. Reading and writing skills are not skills that develop independently of other language skills. Therefore, it can be said that the student needs intensive listening, speaking and reading activities based on his needs, and that the writing process can support the development of language skills together with these.

Various studies have shown that starting to use a cochlear implant in the early stages of life leads to improvements in oral language skills, which can be directly reflected in reading and writing skills (Geers & Hayes, 2011; Mayer et al., 2016; Vital et al., 2013). However, cochlear implant age alone does not guarantee the development of academic skills. Audiological and educational factors such as pre-implant device use, maximum benefit from devices, family education, early education conditions and the nature of educational programs can also have an impact on academic success in subsequent years (Arfe et al., 2016; Mayer et al., 2016; Mayer & Trezek, 2018; Vital et al., 2013). Another noteworthy finding in the current study is that although both participants had implants at similar ages and attended similar educational institutions, there was a difference between their written expression performances, and the corrections they needed varied during the editing and revising of written products. Background check of the participants revealed that Beyza used both the cochlear implant and the hearing aid regularly from an early age, and her audiological evaluations and device maintenance were performed regularly, while Yunus had problems with the internal and external parts of the device at an early age and therefore could not use his device efficiently. Similarly, it has been stated in various studies that written expression performance, as well as other academic skills, may vary among students who can fully benefit from cochlear implant and students who use the device in intervals (Geers et al., 2007; Geers & Hayes, 2011; Mayer & Trezek, 2018). Based on these findings and other research results, it may be recommended to systematically evaluate the development of language and academic skills of these students who are in the same educational environment as their hearing peers and provide support educational services for the areas of need.

As a result, in this research where the process of editing and revising the written products of two students with cochlear implant in an inclusive environment was examined, it was observed that although the written expression performances of both students varied, they benefited from the editing and revising practices performed in one-on-one sessions, they were able to share their experiences in the preliminary writing stage, they were able to write stories about the subject in accordance with these experiences, and the editing and revising process contributes to the quality of written products.

Limitations and Suggestions

This research is limited to the sequential cards and single cards used in the preparation study, which are effective in creating the content of written products. The use of different types of materials in the preparation process may affect the quality of written products. Although conducting the research with two students allows for an in-depth examination of the data, it may limit the generalizability of the research results.

Based on the research results, the following suggestions can be made for future research and practice: In future research, the contribution of various audio and visual materials to the quality of written products can be examined with longitudinal studies. Examining the entire writing process can serve to determine the areas where students with hearing loss need support in the process. In addition, there is a need for research comparing the written expression skills of students with hearing loss in inclusive environments with their peers with typical hearing and interpreting the results.

The current research results show the importance of editing and revising written products in a one-on-one environment under the guidance of the teacher. In practices carried out with students with hearing loss in educational environments, it can be recommended that preliminary preparation studies be carried out and editing and revising studies be carried out before obtaining written products. In addition, since the implementation of activities aimed at other language skills as a whole will support the development of written expression skills, it is important to carry out practices aimed at the development of all language skills with students with hearing loss.

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English Language Teaching in Ecuadorian Primary Schools: Teacher Beliefs in the Context of the Curriculum Reform Versus Actual Practices

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Abstract

Despite curriculum innovations that aim to teach English through current methodologies and approaches, research in English Language Teaching at primary schools has yet to be thoroughly explored. This study examined the impact of the Ecuadorian national curriculum on teaching English as a Foreign Language (EFL) through the lens of primary school teachers' beliefs. The participants in this study were 113 EFL teachers from primary schools. This study applied a mixed-method sequential explanatory approach. The quantitative data were collected using a questionnaire that associated teachers' beliefs and classroom practices regarding the new curriculum reform introduced by the Ecuadorian Ministry of Education. To collect qualitative data, semi-structured interviews were conducted with 12 teachers who participated voluntarily in this stage of the investigation, aiming to support the quantitative results by exploring their beliefs about instructional design, assessment, teaching materials, and classroom teaching practices. The qualitative and quantitative analysis of the gathered data reveals that primary EFL teachers perceive the new curriculum reform as an innovative and updated document that emphasizes the development of 21st-century skills through its core principles. However, participants do not apply these principles effectively due to various factors that prevent them from utilizing current teaching methods. These factors included excessive students per class, insufficient technology integration, a lack of parental involvement, low experience of teaching English at primary schools, and limited quality resources for EFL primary classrooms. The study also offers practical implications for EFL teaching and provides suggestions for future educational endeavors.

Keywords:

EFL curriculum reform, Language education, Pedagogical practices, Primary education, Teacher beliefs

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Introduction

English is a universal language since it is used by many people worldwide. Teaching English as a Foreign Language is taught as a compulsory subject in many countries due to its popularity and importance for students' academic success (Vu & Peters, 2021; Zhang, 2021; Macalister & Nation, 2019). Thus, English language learning for academic purposes can occur at different levels, from young children in primary schools to teenagers in secondary schools and adults at universities. Regarding primary schools, introducing languages is probably the most significant policy development in education due to various internal and external challenges, such as limited opportunities to use the language, motivation, identity, lack of learning resources, teachers' level of English, and class size (Tamayo et al., 2023; Cahyaty & Madya, 2019; Johnstone, 2009).

Several studies have been conducted to investigate language teachers' beliefs about teaching English as a foreign language in primary schools. For instance, in one study, Sulistiyo et al. (2019) described that Indonesian teachers consider teaching English as a foreign language in primary schools to be a challenging process due to the lack of teaching training to teach English to young learners and the lack of technological equipment that obstructs teachers from designing authentic resources, instruction, and assessment that need to be age appropriate. Kalaycı and Ergül (2020) stated that most primary school teachers are aware of the importance of parental involvement in teaching English to young learners, as it can reinforce students' language development in both academic and motivational ways. Furthermore, Copland et al. (2013) claimed that teaching in primary schools is challenging due to various factors, including maintaining student discipline, managing large classes, and gaining experience teaching young learners. Therefore, primary teachers must apply innovative and meaningful strategies to engage with parents and encourage students to learn English by promoting their language, literacy, and communication skills (Grigg, 2022).

Given the importance of family influence and students' encouragement in English learning, national policies must be established to align these factors with effective language instruction (Spolsky, 2021). In this way, this significant influence needs to be addressed in national curriculums to fulfill learning goals for language proficiency. However, while various investigations emphasize the importance of parental involvement and students' motivation to learn a language (Kalaycı & Ergül, 2020; Garton & Copland, 2019; Sulistiyo et al., 2019), the extent to which the Ecuadorian national curriculum incorporates these elements remains uncertain. It creates a need to understand the gaps between policy objectives and classroom realities to improve students' English language proficiency outcomes.

The Ecuadorian Ministry of Education implemented the English as a Foreign Language curriculum, which aimed "to support the policy of developing citizens in Ecuador who can communicate effectively in today's globalized world" (Ecuadorian Ministry of Education, 2016). This curriculum supports students' general education goals of justice, innovation, and solidarity in the context of language learning. Benalcázar and Ortega (2019) explained that, according to the national curriculum, Ecuadorian EFL students at the end of secondary school are expected to achieve the B1 level, as defined by the Common European Framework of Reference for Languages. However, this is not the reality of ELT in Ecuador. According to the English First Organization (2023), Ecuadorian EFL students obtained one of the lowest English proficiency scores among 113 countries worldwide, indicating an inefficient alignment between the curriculum and the actual results.

Further research is needed on the English as a Foreign Language teaching and learning process in Ecuadorian primary schools. For instance, Copland et al. (2014) report a need for more research on teaching English to young learners worldwide, as investigations are more often focused on specific contexts. Likewise, Avci (2023) claims that most studies in EFL contexts are primarily conducted on teenagers and adult learners. This highlights the limited attention that research has given to teachers' beliefs on teaching English as a foreign language (EFL) in primary schools. Consequently, to fill this research gap, this study examines teachers' beliefs about the factors that hinder the authentic connection between the new curriculum principles established by the Ministry of Education and their teaching practices.

Literature Review

Teacher Beliefs in Language Teaching

Teacher beliefs play a crucial role in shaping educational practices, student engagement, and learning outcomes in language teaching. Their "beliefs and practices have been agreed upon as an initially vital basis for continuing a qualified learning process" (Pusparini et al., 2021, p. 147). Motloung et al. (2021) claimed that teachers' beliefs are often grounded in diverse pedagogical and educational philosophies, as well as personal experiences, which influence their choices and practices in curriculum design, language acquisition, classroom management, and teaching strategies to support language learners. Therefore, beliefs are crucial in the learning process, shedding light on their applications in the classroom and the extent to which educational reforms are successful (Bay, 2014; Cheung & Hennebry, 2023).

According to Gao and Cui (2022), one aspect of pedagogical beliefs encompasses two broad types: the constructivist approach, in which students actively participate in the learning process, and the transmissive approach, where teachers present knowledge and students are passive recipients of it. Constructivist believers promote students' interactions by creating an active and dynamic learning environment and using authentic and meaningful strategies to foster students' deep understanding, critical thinking, lifelong learning, and autonomy (Quoc et al., 2023). On the other hand, the transmissive framework relies on traditional teaching methods, which involve the passive transfer of knowledge from the teacher to the students through lectures, readings, and guided problem-solving (Svensson et al., 2017; Kiely & Davis, 2010).

In teaching English as a Foreign language, teachers' beliefs also play a crucial role, depending on their teaching philosophy, cultural context, and pedagogical background. Borg (2017) stated that teachers' beliefs encompass language learning and pedagogical strategies to be applied to foster learners' knowledge and English skills. Furthermore, positive beliefs among English teachers are correlated with effective teaching practices (Shin et al., 2021). Thus, well-founded beliefs about language teaching can shape classroom practices in an engaging, supportive, and interactive environment, allowing teachers to critically reflect on their teaching practices and promote students' English skills development.

Practices in English Language Teaching for Primary Schools

Different teaching methods and approaches were introduced long ago to teach young learners English as a Foreign Language. Setiyadi (2020) explained that these methods and approaches derive from different theories and assumptions about the nature of language. For instance, translation into a second language through grammar use (Grammar Translation Method), the ability to use the language orally (The Direct Method), sounds with specific meanings (The Silent Way), spoken utterances of the average person (Audio Lingual Method), and a set of grammatical rules and language chunks (Total Physical Response), a system for the expression of meaning (Communicative Language Teaching), learning of content and the simultaneous learning of a foreign language (CLIL), or involving students to design, develop, and construct hands-on solutions to a problem (Project-based Approach) (Khasawneh, 2022; Cremin, 2022; Ecuadorian Ministry of Education, 2016; Stakanova & Tolstikhina, 2014).

Due to recent educational trends in addressing the challenges of globalization, teaching English as a Foreign language is a core aspect of both national and school curricula. The national curriculum in countries where English is not spoken as a second language typically outlines guiding principles to ensure consistent and high-quality education across all schools. Currently, the main principles are focused on Communicative Language Teaching (CLT), Content and Language Integrated Learning (CLIL), learner-centered approach, and inclusivity and differentiation, where students can develop their thinking, social, and creative skills needed for lifelong learning (Zhang, 2021; Macalister & Nation, 2019; Ecuadorian Ministry of Education, 2016). Furthermore, in connection with EFL teaching and assessment, the language curriculum is based on the Common European Framework of Reference (CEFR), developed by the Council of Europe, which has, as its primary objective, the description of how learners progress through different stages of learning (Fraga, 2021; Council of Europe, 2018).

Teaching English to young learners requires a thoughtful blend of methodologies and strategies that cater to students' emotional, cognitive, and linguistic development. Shaturaev (2023) claimed that one of the primary roles of teachers is to employ various methodologies, strategies, and means to enhance students' language skills. Teachers must stay current with various approaches to prioritize interaction and authentic communication by integrating technology and designing activities that foster 21st-century student skills to support English learning both inside and outside the classroom (Ekizer & Yildirim, 2023; Parker, 2023; Abdukhayotovna, 2022). Finally, it is essential to be aware of the existing critical issues in primary school contexts, including the starting age, the role of English in the curriculum, motivation, parental involvement, large and under-resourced classrooms, and limited exposure to the English language outside the classroom (Garton & Copland, 2019). Thus, teaching EFL in primary schools requires meeting specific educational qualifications, having practical experience, and possessing pedagogical and soft skills to help improve students' cognitive, emotional, and social development.

Challenges in English Language Teaching at the Primary Level

Regarding teaching English in a foreign context, institutional, instructional, and socio-economic factors hinder students from developing their language skills quickly (Chen, 2022; Kızıldağ, 2009). Regarding teaching English as a Foreign Language (EFL) in primary schools, the instructional challenges include a heavy workload, inadequate basic infrastructure, crowded classrooms, limited contact hours, a lack of skilled and trained teachers, limited parental involvement and support, and excessive reliance on the native language (L1). Likewise, socio-economic factors involve working with students from low socio-economic backgrounds to determine access to educational resources, such as

quality textbooks and technological tools (Case, 2023). Finally, the instructional challenges include unrealistic learning goals and a need for supplementary materials and technological resources (Cahyati & Madya, 2018; Milon, 2016).

Teachers' beliefs about teaching English to young learners are crucial to teaching practices and students' performance. Roothooft (2017) claimed that teachers believe young learners benefit from a communicative approach, as it exposes children to extensive input from the target language. Likewise, they believe that incorporating songs, games, collaborative work, and authentic projects helps students enhance their language skills. However, some studies indicated that there are specific challenges in teaching English to young learners, including the role of parents in supporting language development at home, the lack of training for teachers to work with young learners, limited exposure to authentic contexts, and inadequate technological resources (Nkengbeza et al., 2022; Khulel, 2021; Sulistiyo et al., 2019).

Regarding family involvement, Khulel (2021) stated that parental income, educational background, and occupation are connected to students' academic English development and motivation to learn this language. Therefore, it is an important aspect that can reinforce or diminish students' motivation and encouragement to learn English (Kalaycı & Ergül, 2020). Likewise, Sulistiyo et al. (2019) noted that primary school EFL teachers often lack sufficient experience in employing age-appropriate strategies and maintaining a disciplined classroom environment, which may hinder students' improvement of their language skills. Finally, Nkengbeza et al. (2022) noted that primary English teachers encounter challenges when integrating media technology due to the scarcity of ICT resources in schools and a lack of appropriate skills and training in technology.

The studies reviewed above examine the factors that influence English language teaching in primary schools across various EFL contexts. However, there is little empirical evidence regarding teachers' perspectives on teaching English in primary schools in EFL contexts, such as in Ecuador. Extending the area of interest and the scope of the research, the current study was conducted to explore the factors affecting English language teaching among Ecuadorian primary school teachers. Consequently, the following research questions guided this study:

1. What are EFL teachers' beliefs about teaching English as a Foreign Language in Ecuadorian primary schools?

2. What are the practices of EFL teachers in teaching English as a Foreign Language in Ecuadorian primary schools within the context of curriculum reform?

Methodology

This study employed a mixed-methods sequential explanatory approach to gain in-depth insights into teachers' beliefs about the factors that influence EFL teaching practices in Ecuadorian primary schools. It is argued that this research design incorporates both qualitative and quantitative methods in two distinct phases, utilizing qualitative findings to explain and expand on the quantitative results, thereby understanding the complex phenomena of social worlds through multiple perspectives (Creswell, 1999; Dawadi et al., 2021; Malina et al., 2011). The quantitative data were collected using a questionnaire that associated teachers' beliefs and classroom practices regarding the new curriculum reform provided by the Ecuadorian Ministry of Education. Likewise, for qualitative data, semi-structured interviews were conducted with 12 teachers who participated voluntarily in this investigation stage to support the quantitative results by providing their insights into instructional design, assessment, teaching materials, and classroom teaching practices.

Context

This study was conducted with Ecuadorian primary EFL teachers in schools where English is a mandatory subject. In this regard, primary and secondary education strictly adhere to policies and regulations established by the Ministry of Education in the Ecuadorian National Curriculum (Ecuadorian Ministry of Education, 2016). This curriculum is designed for students whose mother tongue is not English, and it proposes three main objectives for English language learning: Developing students' understanding of the world and its cultures; fostering personal, social, and intellectual skills; and cultivating a love of language learning from an early stage. Likewise, its main principles focus on the Communicative Language Approach, Content and Language Integrated Learning, Lifelong Learning, the Common European Framework of Reference standards, and a Learner-Centered approach.

Participants

The participants were selected by applying a convenience sampling method. Emerson (2021) claimed that in this method, the enrolled participants fit the study's criteria, such as availability, willingness, or easy access to contact. Thus, in this study, 113 EFL teachers from public primary schools participated in the first data collection stage by answering a questionnaire. After that, 12 teachers participated in the interview process due to their availability, accessibility, and willingness to participate. All participants worked as EFL teachers at Ecuadorian public primary schools during the data collection and were from the four regions of Ecuador: The Highlands,

Coast, Amazon, and the Galapagos Islands. Their native language was Spanish, and they had over five years of experience teaching EFL. Of the 113 teachers, 70 held a bachelor's degree in EFL teaching, 10 had a master's degree in teaching EFL, and the remaining 33 held other bachelor's degrees in primary education, information technology, social studies, and sciences. On the other hand, the 12 teachers who participated in the interview met the criteria for holding a bachelor's or master's degree in teaching EFL for more than five years in primary schools and were willing to participate in this stage of the research voluntarily. All teachers were familiar with the Ecuadorian national curriculum principles established by the Ministry of Education.

Instruments

The first stage of this study involved administering a questionnaire to explore teachers' beliefs about the connections between Ecuadorian national curriculum principles and their teaching practices in primary schools. The questionnaire consisted of twenty questions using a Likert scale; its criteria were strongly agree, agree, neutral, disagree, and strongly disagree. Furthermore, it comprised five constructs: curriculum, teaching materials and technology, parental involvement, teaching experience, and possible factors that hinder language learning. After completing the questionnaire, the teachers who agreed to participate in the interview were contacted in the second phase. This phase aimed to gain in-depth insight into the results obtained from the questionnaires; therefore, 12 teachers participated voluntarily, sharing their beliefs about English Language Teaching in primary schools. Each interview consisted of eight questions and lasted a maximum of thirty minutes, divided into sections covering introduction, instructional design, assessment, teaching materials, and teaching practices.

Validity and Reliability of the Instruments

The research instruments received expert judgment and were piloted to ensure the collected data was accurate and consistent (Csizér, 2020). The feedback provided helped the researchers refine two questions that were unclear due to their wording and technical concepts. A Cronbach's alpha coefficient was calculated to show the reliability of the research instrument. As shown in Table 1, the internal consistency of the questionnaire was good across all sections. Sections such as teaching experience and parental involvement showed high consistency (0.87 each), with factors hindering language learning having the highest consistency (0.90).

Table 1

Cronbach's alpha internal consistency coefficient of the questionnaire constructs.

Construct	Internal consistency
Curriculum	0.71
Teaching materials/technology	0.80
Parental involvement	0.87
Teaching experience	0.87
Possible factors that hinder language learning	0.90

Data Analysis

This study employed both qualitative and quantitative methods to address the research questions. Descriptive statistics were applied to collate and analyze the quantitative data. The SPSS software was used to calculate means, percentages, and frequencies, as well as to perform Cronbach's alpha coefficient reliability test on the questionnaire. For the qualitative data, the interview content was transcribed, coded, and analyzed through a thematic analysis, which involves identifying repeated meanings across a dataset to interpret the phenomenon (Xu & Zammit, 2020).

Results

This section presents the findings in response to the research questions that guided this study. It highlights critical areas of concern and optimism among teachers regarding English language teaching in primary schools. The data reflect diverse attitudes towards the national curriculum, teaching methods, parental involvement, and available resources for teaching English as a foreign language (EFL), shedding light on potential areas for improvement in the English language education system. From the Likert scale options, the terms disagree and strongly disagree were considered negative perceptions that refer to teachers' insights into teaching English in primary schools.

Category A: Teaching English as a Foreign Language in Ecuadorian primary schools in the context of the curriculum reform

Analyses of the interview and questionnaire results indicated that all teachers perceive an incongruence between the principles stipulated in the Ecuadorian national curriculum and their teaching practices. Table 2 presents the main results related to these inconsistencies, specifically the relevance of the curriculum for students from diverse cultural and socio-economic backgrounds, the equitable development of language learners' skills, the resources provided for EFL in public schools, and the support for parental involvement in language learning.

Based on Table 2, the findings suggest that 50% of teachers disagree and 30% strongly disagree that the Ecuadorian National Curriculum, as provided by the Ministry of Education, supports their teaching practices; only 20% feel optimistic about it. Most participants (40% strongly agree and 10% agree) believe that the curriculum enables the flexible incorporation of innovative teaching practices.

Teacher A, for instance, stated that

> *Although, according to the Ministry of Education, teachers adapt the curriculum principles outlined in the syllabus, there needs to be a match between the curriculum standards and the actual implementation or outcomes in our schools and classrooms. The curriculum could be more ambitious, with too many objectives that are impossible to achieve due to different factors.*

Furthermore, only 20% of teachers perceive the curriculum as relevant to learners' diverse cultural and socio-economic backgrounds. Likewise, the statements indicate that many teachers felt their students needed more engagement with the content (60%) and resources (70%) provided by the Ministry of Education. The following teachers' statements support these results:

> *Different factors, such as the economic resources and geographic location of the schools and students, lead to unequal implementation of the national curriculum provided by the Ministry of Education. For instance, even though the curriculum emphasizes technological integration, this integration remains a utopia. (Teacher C).*

> *Even when the curriculum requires the implementation of innovative and current teaching strategies, the material provided by MINEDUC needs to be more engaging and relevant to capture students' attention and motivate them to learn. (Teacher B). Likewise, Teacher D explained that MINEDUC only provides digital resources, including textbooks, which could be more effective but may also lead to a lack of student participation.*

According to the participants, the curriculum must effectively support or promote English skills development among primary students. Sixty percent of teachers disagree, 30% strongly disagree, and another 30% strongly agree with the statement that the curriculum encourages students to develop primary English skills. Additionally, only 10% of teachers strongly agree or agree that the educational resources provided by MINEDUC effectively enhance students' language skills. This is illustrated in the following examples:

> *Although the Ecuadorian curriculum is well-organized, the proposed teaching approaches and methods must align with our reality, making them irrelevant to our students. The primary constraint, for instance, is the need for more technological tools and the Internet in schools. (Teacher C).*

> *The national curriculum needs to focus on critical language areas. For instance, it covers some aspects of language, such as writing, reading, and grammar, but it needs to address speaking skills, which can hinder well-rounded language development. (Teacher G).*

> *One of the main principles of the curriculum is the application of Communicative Language Teaching; however, this does not occur for various reasons. For instance, there need to be more opportunities to practice the language and a lack of authentic resources that could allow them to increase their English skills. (Teacher B).*

Finally, regarding parent involvement, 80% of teachers strongly disagreed that the curriculum encouraged parent involvement in language learners. On the other hand, 90% of teachers strongly agreed, and 10% agreed that parental involvement has a positive effect on students' motivation to learn English. Teacher K claimed that parental involvement is crucial for motivating language learners at primary and secondary schools; however, the curriculum must promote this involvement. Likewise, Teacher D stated that the current curriculum needs to provide adequate structures for parents to engage with or support their children's language learning. Finally, Teacher C recognized the value of parental support, indicating that parents play a crucial role in increasing students' enthusiasm and effort in the English language. However, he explained that the curriculum needs to address clear instructions and engagement activities for parents to support their child's language learning at home.

Category B: Teachers' practices in teaching EFL in Ecuadorian primary schools

The results presented in Table 3 indicate that teachers employ diverse methodologies, with some favoring traditional approaches and others adopting communicative or interactive methodologies. According to the teachers' beliefs, the high-usage methods applied by teachers in primary schools are Content Language Integrated Teaching (80%), the Audiolingual Method (80%), and the Grammar-Translation Method (80%). Additionally, teachers employ moderate-usage methods, including task-based language teaching (70%), communicative language teaching, and a language-centered approach (60%). Finally, the low-usage percentages of applications, according to the data, are Direct-Method (30%), Total Physical Response (30%), and Silent Way (20%). The following extracts support the results addressed:

> *I prefer applying Content and Language Integrated Learning in the classroom because it enables me to integrate language learning with the content of other subjects, such as science, culture, and history. (Teacher F).*

> *Using repetitions and drills, as well as patterns of speech in listening exercises, are my favorite techniques for developing the language habits of my young students. (Teacher A).*

Although the grammar-translation method is considered traditional, providing a clear language structure is beneficial as it helps students communicate effectively later. (Teacher B).

Applying the Direct Method is challenging, according to our reality. Even when this method may be relevant to teaching young learners, it is limited for almost all students. (Teacher L).

Applying Task-Based Language Teaching is one of my favorite methods of teaching young learners. It enables me to engage in meaningful tasks that foster student interaction and communication. (Teacher D).

I have adopted the student-centered approach in my classes, as it enables learners to take responsibility for their learning. However, with young children, it can be challenging. Therefore, I prefer applying other methods, such as Task-Based Language Teaching. (Teacher F).

Category C: Factors that influence the English Language Teaching in Primary Schools

According to Table 4, English teachers in primary schools agreed with all the factors that influence EFL in Ecuador. The first challenge is related to

Table 2

Percentages of teachers' beliefs about teaching English in primary schools

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
The curriculum principles support your teaching practices.	10%	10%	0%	50%	30%
The curriculum offers sufficient flexibility to incorporate innovative teaching practices.	40%	10%	30%	20%	0%
The curriculum is relevant to your students' diverse cultural and socio-economic backgrounds.	0%	20%	50%	20%	10%
The curriculum encourages the efficient development of primary English skills.	10%	20%	10%	30%	30%
The students appear to be engaged with the curriculum content provided by the Ministry of Education.	0%	20%	20%	60%	0%
The quality of educational resources provided by the Ministry of Education is satisfactory for students' language learning.	0%	10%	20%	50%	20%
The Ministry of Education's educational resources enable students to develop their language skills efficiently.	0%	10%	20%	50%	20%
Technology is incorporated into teaching in primary schools.	20%	20%	20%	40%	0%
The curriculum supports parental involvement in student learning.	0%	0%	20%	50%	30%
Parental involvement motivates students in language learning.	90%	10%	0%	0%	0%

Table 3

Percentages of teaching methods applied for teaching English in primary schools.

Teaching Methods applied by teachers in primary schools	Number of teachers	Percentage of application	Mean	Standard Deviation
Communicative Language Teaching (CLT)	68	60%	60.18	5.2
Content and Language Integrated Learning (CLIL)	90	80%	79.65	4.28
Learner-centered Approach	68	60%	60.18	5.2
The Audiolingual Method	90	80%	79.65	4.28
Grammar-Translation Method	90	80%	79.65	4.28
Direct Method	34	30%	30.08	4.88
Silent Way	23	20%	20.35	4.28
Task-Based Language Teaching (TBLT)	79	70%	69.91	4.88
Total Physical Response (TPR)	34	30%	30.1	4.88

Table 4

Percentages of teachers' beliefs about the factors that influence ELT in primary schools

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Parents, collaborate with your teaching practices.	10%	10%	20%	40%	20%
Do you think students have enough contact hours to practice their English skills?	0%	10%	10%	60%	20%
Does the number of students per class help you to conduct all the teaching strategies efficiently?	0%	10%	20%	50%	20%
All students in your class have access to the technology needed for learning.	0%	10%	10%	50%	30%
The teachers are skilled and trained to teach in primary schools.	0%	10%	10%	50%	30%
Do you have sufficient experience working at the primary school level?	20%	20%	0%	40%	20%
Do you have enough experience using strategies to teach young learners?	20%	10%	10%	40%	20%
Creating a disciplined and friendly classroom environment in primary schools is easy.	10%	20%	20%	40%	10%
The use of L1 in the classroom is a factor that hinders students' L2 improvement.	10%	20%	50%	10%	10%
Are your students exposed to sufficient L2 interaction outside the classroom?	10%	20%	0%	50%	20%

parental involvement. Although teachers recognize the vital role parents play in the students' learning process, 40% of teachers strongly disagree, and 20% disagree that parents collaborate with their teaching practices. Teacher B, for instance, stated that parental involvement is considered an essential factor in teaching EFL; however, sometimes parents overstep professional boundaries. Instead of helping, they tend to overwhelm and disrupt classroom routines. On the other hand, Teacher E claimed that instead of helping their children, parents often find ways to shield them from failure or expect immediate language success, which can lead to disagreements between teachers and students.

The participants also found that instructional challenges influence ELT in primary schools, specifically in terms of students' contact hours, the number of students per class, and the lack of technology in the classroom. Regarding the number of contact hours, 60% of the participants disagreed, and 20% strongly disagreed, that students had enough hours per week to practice the target language. On the other hand, only 10% of the teachers agreed that the number of students per class helped them conduct the planned strategies efficiently. Regarding students' access to technology, most teachers (80%) believed that students do not have access to technological tools and the Internet, which is a relevant factor in teaching in primary schools.

> *In public primary schools, students receive only three 45-minute English lessons per week, with each class typically having an average of 40 students. The limited time and excessive number of students prevent them from engaging in classroom speaking, listening, writing, and reading tasks. As a result, it is challenging to authentically cover interactive activities such as group discussions or role-plays. (Teacher F).*

> *A teacher is tasked with teaching English to a class of 40 or 45 students. Due to the large number of students, managing noise and ensuring each student receives sufficient speaking practice is nearly impossible. Likewise, students from public schools rarely have access to technology tools and the Internet; therefore, they are limited to using printed materials in class and rely solely on the teacher's instruction. (Teacher G).*

It was remarkable that only 40% of teachers considered themselves to have enough experience teaching English in primary schools. Likewise, 30% of teachers considered having enough experience using specific strategies to teach young learners. The following teachers explained these obtained results:

> *The authorities are responsible for assigning the teachers for the whole school year. Unfortunately, teachers are assigned according to the institution's needs. In this case, some teachers are required to teach English without any prior knowledge of the subject due to a lack of English teachers. Therefore, most teachers need to acquire specific pedagogical knowledge, which can lead to a lack of motivation to learn English. (Teacher C).*

> *In my case, I have more experience working with teenagers and adults. When I was assigned to teach children, it was challenging because I needed to fully understand the developmental stages of primary school students. Additionally, I have had difficulties managing a classroom of young children, as I often struggle to maintain discipline and control. (Teacher L).*

Regarding the classroom environment, 40% of teachers disagree, and 10% strongly disagree that creating a disciplined and friendly classroom is easy. In this regard, Teacher E stated that working with children, in general, is not easy. Managing a classroom goes beyond simply enforcing rules or creating a friendly atmosphere; it involves addressing the unpredictable needs of children's emotions, behavior, and learning. Likewise, Teacher L explained that working with children involves managing an unpredictable classroom environment and maintaining a balance between discipline and friendliness.

Finally, the data shows that 50% of teachers are neutral about using L1 in the EFL contexts. This finding suggests that teachers are undecided or see both benefits and challenges to incorporating the students' native language when teaching English. For instance, Teacher B indicated that if L1 is used strategically in the classroom, it will help teachers save time on lengthy explanations in L2 and keep students focused on English learning without overwhelming them. Likewise, Teacher J claimed that L1 can sometimes help explain complex concepts and provide students with more confidence to use the L2 language. Therefore, to reduce students' anxiety.

Discussion

This study focused on the English language teachers' beliefs about teaching English in primary schools within the context of curriculum reform and the challenges they face in actual practice. In general, the analysis of the questionnaires and interviews revealed that, according to the participants' perceptions, the principles established in the national curriculum are not effectively aligned with actual teaching practices in English education at public primary schools in Ecuador. The teachers highlighted various inconsistencies related to the relevance of the curriculum for students from diverse cultural and socio-economic backgrounds, the equitable development of language learners' skills, the allocation of resources for EFL in public schools, and the support for parental involvement in language learning. Furthermore, they indicated that the objectives provided by the national curriculum are too rigid and decontextualized in relation to Ecuadorian reality. While the curriculum promotes communicative competence, the classroom realities do not align with that vision. These inconsistencies are shown in the low scores obtained by the Ecuadorian students on the English proficiency

test (English First Organization, 2023). These findings are supported by existing literature that indicates instructional, institutional, and socio-economic factors hinder students from developing their language skills quickly (Shaturaev, 2023; Sulistivo et al., 2020; Copland et al., 2013; Kızıldağ, 2009). Moreover, Case (2023) noted that the language curriculum primarily focuses on instructional aspects. Thus, leaving out the students' socio-economic backgrounds could be a significant factor in determining access to technological tools, interactive resources, and quality educational resources.

Due to the aforementioned reasons, the results also indicated that teachers employ diverse methodologies, with some favoring traditional approaches and others embracing communicative or interactive methodologies, including the high-usage methods such as Content-Language Integrated Teaching, the Audiolingual Method, and the Grammar-Translation Method. Additionally, teachers employ moderate-usage methods, including Task-Based Language Teaching, Communicative Language Teaching, and a Language-centered Approach. Finally, the low-usage methods are Direct-Method, Total Physical Response, and Silent Way. The teachers indicated that even when the Ecuadorian Ministry of Education (MINEDUC, 2016) requires teachers to apply innovative and current approaches, the reality in public primary schools in Ecuador differs. They found the curriculum to be a relevant and well-organized document for EFL teaching; however, some constraints hinder the application of the curricular principles stipulated. The main factors are related to the contextualization of the curriculum, the lack of technological tools, instructional factors, and the lack of opportunities to use the language authentically. Zhang (2021) emphasized the importance of employing current and innovative teaching strategies to enhance students' thinking, creative, and social skills, which are essential for lifelong learning. Likewise, the Common European Framework of Reference (Council of Europe, 2018) suggests that teachers employ various strategies, such as CLT (a Language-Centered approach) and TBLT, for EFL teaching and assessment to monitor learners' progress through different stages of learning. However, following the results of this study, Shaturaev (2023) claimed that teaching English in primary schools requires a thoughtful blend of strategies and methodologies to foster students' linguistic development and emotional and cognitive improvement. Likewise, Garton and Copland (2019) stated that applying different teaching strategies in primary schools is challenging, as teachers must be aware of critical issues such as students' motivation, parental involvement, large under-resourced classrooms, and the limited exposure of English to authentic contexts. Therefore, teachers at primary schools must have experience in applying age-appropriate strategies to help students develop their English skills (Sulistiyo et al., 2019).

Furthermore, teachers believe that key instructional challenges, limited contact hours, large class sizes, and limited access to technology and the Internet are the primary factors hindering English Language Teaching in primary schools. These factors hinder and limit the application of effective teaching strategies, depriving students of valuable technological resources that could enhance their English language learning. Kızıldağ (2009) classified these educational issues as institutional, instructional, and socio-economic factors that hinder students from developing their language skills efficiently. When contact hours for learning English are limited, students have fewer opportunities to engage in English activities and actively participate in the classroom, which slows down their language development (Chen, 2022; Kızıldağ, 2009). Likewise, Cahyaty and Madya (2019) stated that working with large class sizes restricts students' dynamic interactions and forces teachers to adopt a teacher-centered approach, which is not advisable for promoting active learner participation. Finally, teachers perceived that they needed more technological resources and Internet access to use interactive, visual, and engaging materials for their students. The reality in Ecuador is different from that in other developed countries, such as the United States or Finland, where technology is provided to teachers and students more efficiently. Thus, the limited technology in EFL classrooms reduces access to authentic and meaningful resources, hindering students' ability to develop their language skills (Nkengbeza et al., 2022).

One remarkable finding from this investigation is that most teachers lack sufficient experience teaching English at primary schools, which can be an essential factor hindering students' practical English skills. Copland et al. (2013) supported this finding by indicating that most teachers have more experience working at secondary and university levels, which can be challenging when transitioning to primary schools, where maintaining discipline, managing classes, and applying teaching strategies can be particularly demanding at this educational level. Therefore, inexperienced teachers working with young children may need to thoroughly understand the developmental stages of primary school children. Another interesting finding is related to the importance of parents in enhancing students' English proficiency. Due to the limitations in English teaching in Ecuador, according to the participants, parental involvement plays a crucial role, as it helps students reinforce their knowledge outside the classroom and motivates them to continue learning. Thus, parental involvement is vital for young learners to help them meet specific language standards and improve their cognitive, emotional, and social development skills (Kalaycı & Ergül, 2020; Garton & Copland, 2019).

Conclusions

This study offers valuable insights into the beliefs of Ecuadorian English as a Foreign Language (EFL) teachers regarding the challenges of implementing Ecuador's English language curriculum in primary schools. The findings revealed a significant misalignment between the Ecuadorian language curriculum and actual practices in primary schools. The teachers indicated that the national curriculum needs to align its principles with institutional, instructional, and socio-economic factors reflected in low student performance on English proficiency assessment. The leading challenges include heavy workload, basic technological infrastructure, crowded classrooms, limited contact hours, and excessive (L1) language use. Moreover, working with low socio-economic levels is another issue that impairs students' access to educational resources such as quality textbooks and technological tools.

Additionally, the lack of experienced teachers in primary school education and minimal parental involvement in students' learning complicate effective language instruction in Ecuadorian primary schools. To address these educational and contextual issues, teachers employ different traditional and innovative methods, such as the Grammar-Translation method, the audiolingual approach, and Content-Language Integrated Teaching, to teach young learners in primary schools. On the other hand, Task-Based Language Teaching (TBLT) and Communicative Language Teaching (CLT) are used less frequently, despite the recommendations from the Ecuadorian Ministry of Education and the Common European Framework of Reference. A notable challenge is the teachers' limited experience with primary students, as many come from secondary or university backgrounds, which impacts their ability to engage young learners and effectively manage EFL classrooms. Furthermore, limited parental involvement intensifies the challenges, as it prevents parents from supporting English learning outside the classroom and enhancing students' cognitive, social, and emotional skills.

This study has implications for the Ecuadorian Ministry of Education, policymakers, teachers, and researchers working in English language education, as it highlights the primary challenges that primary school teachers face when teaching in EFL contexts. The researchers suggest the need for greater alignment between curriculum principles and classroom realities by increasing the provision of technological resources, providing teacher training for EFL primary education, and fostering parental involvement to contribute to more successful English language learning outcomes in Ecuadorian primary schools. Additionally, the Ministry of Education and policymakers can make adjustments to ensure the curriculum remains practical and effective over time. In this way, professional development programs and teacher training should be created to equip teachers with the skills to adapt curriculum content to diverse classroom realities, fostering innovative teaching practices and current methodologies that align with updated curricular objectives.

The limitations of this study are related to the sample representation. The sample was limited to volunteer participation, which may not fully represent the diverse experiences of teachers across Ecuador. Therefore, it restricts the generalizability of the results to other EFL contexts. Furthermore, the teachers' perceptions are based on self-reported data, which may introduce bias on the part of the participants. Therefore, future research could address the limitations of this study by incorporating classroom observations and specifying the sample to compare primary EFL teachers from urban and rural areas, thereby facilitating a comparative analysis between these contexts. Additionally, investigating students' perspectives and exploring the specific teaching training gaps can provide a more comprehensive view of the effectiveness and challenges of EFL education in primary schools. Finally, to enhance the study's relevance to international elementary education research, it will be crucial to link its findings to global discussions on teaching practices, learning outcomes, and policy implications. Additionally, it is recommended to conduct a comparative study between urban and rural schools or between experienced and novice teachers to provide further insights and enrich the findings of this study.

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Cross-Cutting Approach in the Formation of Critical Thinking of Primary School Learners

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Abstract

The article explores the psychological and pedagogical aspects of developing critical thinking in primary school learners. Its primary objective was to analyze these aspects and experimentally assess the impact of a specially designed system of end-to-end exercises on the level of critical thinking formation in young students. The research hypothesis proposed that integrating a structured system of exercises into the modern primary school curriculum would not only enhance subject mastery but also significantly improve students' critical thinking skills. To test this hypothesis, a range of empirical methods was employed, including diagnostic, observational, prognostic, experimental, and statistical analysis techniques. Students were assigned tasks designed in accordance with critical thinking indicators, and their responses were analyzed. The evaluation of expert assessments confirmed the effectiveness of the selected methodological approach and the implemented system of exercises in actively fostering critical thinking. The results demonstrated a 12.99% increase in the number of students with a high level of critical thinking in the experimental group compared to the control group, a 12.86% rise in those with an average level, and a 25.84% decrease in students with a low level. The study underscores that successfully embedding critical thinking technology in primary education necessitates a systematic approach, teacher preparedness, and a fundamental revision of psychological and pedagogical strategies. This, in turn, will contribute to nurturing a competitive, adaptable, and cognitively proficient young generation.

Keywords:

Critical Thinking, Primary School Learner/Child, Comprehensive Ability, Signs and Levels of Formation, System of Exercises, Expert Assessment, Educational Sector, New Ukrainian School.

Introduction

The contemporary world is undergoing profound transformation amidst the rapid evolution of information and digital realms. These changes, in turn, require new approaches to preparing a person for life through adaptive education. In order to meet the demands of modern society, education must be innovative. One of the most essential

educational innovations today is the formation of schoolchildren's critical thinking.

Critical thinking plays a crucial role in the intellectual and personal development of schoolchildren. It enables them to analyze information objectively, distinguish between facts and opinions and make informed decisions. In an era of information overload and digital transformation, critical thinking helps young learners navigate vast amounts of data, resist manipulation, and develop problem-solving skills. Experts across various scientific disciplines and social spheres emphasize the necessity of fostering critical thinking from an early age. The importance of this skill has been emphasized by experts in various scientific fields and spheres of social life and has been recognized at the conceptual and legislative levels.

In particular, the International Economic Forum in Davos defined critical thinking as a «core skill» that a person needs for successful competition in the labor market and career growth (World Economic Forum, 2016). After all, the intellectual development of a modern person is determined not by the amount of knowledge one has acquired, but by one's readiness to understand and select the necessary information through critical analysis, as well as the ability to independently make optimal decisions.

The purpose of the article was to analyze the psychological and pedagogical aspects of the formation of primary schoolchildren's critical thinking and to experimentally verify the influence of the developed system of exercises of end-to-end application in the educational process on the level of formation of primary school children's critical thinking.

Research hypothesis: the developed system of exercises for end-to-end application in the educational process of a modern primary school can ensure not only in-depth learning of academic subjects, but also a significant increase in the level of primary school learners' critical thinking skills formation.

Literature Review

J. Dewey (1933), E. Glaser (1941), M. Lipman (1988), J. Braus, D. Wood (1993), R. Paul (1993), D. Halpern (1996), W. Sumner (1996) and others are rightfully considered representatives of the development of the critical thinking concept.

The reflection of views on critical thinking in pedagogical theory and practice was represented in the scientific researches in scientific research by scientists: O. Tiahlo (2008), B. Moore, R. Parker (2009), A. Fisher (2011), M. Caceres, M. Nussbaum, O. Pometun (2018), S. Terno (2019), J. Ortiz (2020) P. Kavenuke, M. Kinyota, J. Kayombo (2020), M. Pochynkova (2020), A. Saputro, S. Atun, I. Wilujeng, A. Ariyanto, S. Arifin (2020), R. Sari, S. Sumarmi, I. Astina, D. Utomo, R. Ridhwan (2021), S. Seibert (2021), Davies R., Johnson L., Peters M. (2022), Lee K., Anderson R. (2023), Smith J., Taylor L., Brown C. (2024), etc.

The priority of learners' critical thinking formation was enshrined in normative legal documents and conceptual provisions of Ukraine. According to the Law of Ukraine «On Education» (2017) and the «Concept of the New Ukrainian School» (2016), critical thinking is defined as a skill common to all key competencies needed by every modern person for successful life. In the State Standard of Primary Education (2018), the formation and development of critical thinking is comprehensive and is included in the key competencies of all educational branches.

The analysis of psychological and pedagogical literature showed that it is necessary to actively form and develop critical thinking starting from primary school age. Critical thinking can help the learners of primary education to be flexible, ready for changes; allow to perceive the world as it is; provide an opportunity to analyze and synthesize information, compare facts, disprove myths, establish cause-and-effect relationship, put forward alternatives and evaluate them, recognize fakes, formulate arguments, make optimal decisions and draw own conclusions.

Theoretical Basis

The current stage of the concept of critical thinking development in pedagogical theory is the result of American research in cognitive psychology. J. Dewey is considered the founder of the theory of critical thinking, but in his writings he used the term «reflective thinking», which is consonant with the modern interpretation of critical thinking, namely: «active, persistent and thorough analysis of thought or form of knowledge (scientific fact, problem, hypothesis, idea, theory, – author) taking into account the grounds on which it is based and the analysis of further conclusions to which it leads» (Dewey, 1933, p. 185).

Also, critical thinking in the psychological and pedagogical literature was defined as: «skillful responsible thinking that allows a person to formulate reliable probable judgments» (Lipman, 1988, p. 40); «a particular type of thinking characterized by activity, purposefulness, independence, discipline and reflexivity and involves the development in the learning process of a person's ability to: identify problems, analyze, synthesize, evaluate information from any sources, propose alternatives and evaluate them, choose a way to solve a problem or one's own position in relation to it, and justify one's views, make a conscious choice and act» (Pometun, 2018, p. 94).

The definitive analysis of the key concept of the study showed that despite the significant number of definitions by scientists, their content does not contradict each other, but only reveals certain specific aspects of critical thinking, complements or clarifies them.

The main tool for the formation of critical thinking of a primary school child is a problematic situation containing a contradiction that the child needs to identify and resolve. In the process of working with a problematic situation, a schoolchild encounters a difficulty, which creates favorable conditions for further critical reflection. In this regard, J. Dewey (1933) was convinced that educational material without difficulties was useless, on the other hand, the deliberate avoidance of difficulties in order to prevent mistakes was harmful to the mental development of the schoolchild.

Critical reflection at lessons in elementary school conditions is carried out according to the following generalized algorithm: creation of a problem situation; facing a problem; an attempt to solve difficulties with the help of existing knowledge and methods of action of the schoolchild; proposing hypotheses; restructuring of knowledge, methods of action, own attitudes and experience, development of a new point of view; enlightenment (emergence of the idea of a solution, finding the optimal way to solve the problem by means of analysis through synthesis); justification of the decision; reflection (Caceres, Nussbaum, & Ortiz, 2020). That is, in the process of critical thinking, a primary school child goes through the following step-by-step path: awareness – blockade – enlightenment – resolution – justification – reflection.

Critical thinking ensures the formation of such important personal qualities in primary school learners as the ability to formulate their opinion, justify and defend their own position, make sense of the acquired experience, build a chain of evidence and facts, analyze all the pros and cons, identify contradictions, draw conclusions, etc. (Zaporozhchenko, Shvardak, Stakhiv, Kalyta, Sadova, & Illyash, 2022).

On the other hand, primary school children very often develop uncritical thinking, which is characterized by the fact that they «blindly» fall under the influence of other people, accept the information they hear as true, without properly analyzing it. In order to avoid this or at least weaken the manifestations, it is necessary to form critical thinking through educational activities (through all the educational branches of the primary school).

It is known that the work of teachers is carried out in accordance with the educational programs developed on the basis of the State Standard of Primary Education (2018), Standard educational programs, educational programs of the institution in which they work. In order to adequately determine the signs of critical thinking and their detection in primary school children, we took into account the requirements laid down in the State Standard of Primary Education and two valid Standard Educational Programs (grades 1-2 and 3-4), developed under the leadership of O. Savchenko and R. Shiyan.

We give examples of an end-to-end approach to the formation of critical thinking, which are presented in the State Standard of Primary Education (2018) as requirements for mandatory learning outcomes and competencies of primary school learners in the following educational fields:

> *- linguistic and literary educational field (critically evaluates information in various types of texts, media texts and uses it to enrich one's own experience; expresses thoughts, feelings and attitudes, interacts with other people);*
>
> *- mathematical educational branch (critically evaluates data, the process and the result of solving educational and practical problems);*
>
> *- natural educational branch (aware of the diversity of nature, the interrelationships of its objects and phenomena, explains the role of natural sciences and technology in human life; critically evaluates facts, combines new experience with previously acquired one and creatively uses it to solve problems of a natural nature);*
>
> *- IT educational field (critically evaluates information to solve life problems; consciously uses information and communication technologies and digital devices for access to information, communication and cooperation);*
>
> *- social and health-care educational field (identifies alternatives, predicts consequences, makes decisions in favor of health, well-being, own safety and safety of others; makes reasoned choices in favor of a healthy lifestyle, analyzes and evaluates consequences and risks);*
>
> *- civic and historical educational field (establishes connections between events, people's activities and their results over time; analyzes the content of various sources of social and historical information, critically evaluates them; summarizes information from various sources; presents reasoned judgments about known facts and historical figures, and also about the events of social life).*

After summarizing the requirements for mandatory learning outcomes and competencies of modern primary school learners in various educational fields, we grouped them according to five signs of critical thinking. Namely:

1. Independence and autonomy of thinking (independence of one's own opinion; striving to independently analyze, synthesize, compare information; expressing one's own opinions on problematic and cognitive issues).

2. Resistance to suggestive influence (the ability to notice errors in the judgments or actions of other people; trying to figure out the correctness of certain statements and conclusions; the ability to defend one's own opinion; the lack of fear of disagreeing with the teacher or classmates; the ability to establish cause-and-effect relationships).

3. Self-criticism, self-reflection (seeing one's own mistakes, constructively analyzing them; the ability to adequately evaluate one's knowledge and skills; careful and adequate perception of the comments of the teacher and classmates regarding one's mistakes, shortcomings, certain improvements).

4. Divergent thinking, perceptiveness (the presence of a reasonable amount of doubt regarding any conclusions in the learning process; the ability to see alternative solutions, assess consequences and risks; the desire to find better options for solving a problem situation).

5. The ability for tolerant communicative interaction (efforts to express one's own opinions in a reasoned and logical manner; respectful attitude to the opinions and proposals of opponents; the ability to cooperate with others in order to find a joint optimal solution).

The analysis of the above-mentioned normative documents showed an emphasis on the systematic and cross-cutting formation of critical thinking of primary school children. It has been found that the 4th grade educational programs are most focused on critical thinking, which is related to the age characteristics of primary school learners. An analysis of textbooks recommended by the Ministry of Education and Science of Ukraine has been carried out. Their electronic versions are posted on the website of the Institute for the Modernization of the Content of Education (https://lib.imzo.gov.ua). The analysis of the textbooks (editions were chosen randomly) showed that they still do not sufficiently focus on the development of the ability to notice the erroneous judgments of others; on the desire to understand the correctness of solving educational problems; on the ability to see alternative solutions and doubts about the « only correct» decisions and conclusions. Particular attention, in our opinion, is drawn to attempts to independently comprehend the educational material, find causal relationships, compare, and draw conclusions.

An important feature of the implementation of the technology for the formation of critical thinking at primary school is that it involves synchronous work at two levels. On the one hand, it is necessary to process the program material for each subject with schoolchildren, to form the appropriate competencies; on the other hand, it is also necessary to «teach schoolchildren to learn», show them the process of acquiring knowledge, teach them to analyze, synthesize, compare, formulate their opinion, argue it, see alternatives and contradictions, draw reasonable conclusions, etc. (Kavenuke, Kinyota, & Kayombo, 2020). Particular attention was paid to the formation of the ability to reason about how this process occurs; developing the ability to think about thinking. This is what makes primary school children thinking people, able to perceive new ideas, realize, adapt and apply them in practice in today's changing conditions. Exercises conducted by a teacher using the technology of critical thinking can significantly enhance the formation and development of those competencies that are defined as the main goals of education in the conditions of the New Ukrainian School.

Methods and Materials

The effectiveness of the experimental model for the formation of critical thinking of primary school learners was tested by experimental work on the basis of the Mukachevo secondary school No 13 (Transcarpathian region, Ukraine).

In this institution, the end-to-end implementation of the developed system of exercises into the educational process in the 4th grade and observations and analysis of changes in the formation of critical thinking of primary school children during the school year have been carried out.

Four classes were involved in the research and experimental work. Two classes (60 leaners of primary education) were included in the control group (CG), the other two (63 learners) were included in the experimental group (EG), a total of 123 respondents. The sample consisted of 71 males and 52 females. The mean age of the participants was 9.7 years (*SD* = 0.6). The age range of the primary school learners was from 9 to 11 years. The distribution of demographic characteristics ensured a balanced representation of both genders in the study, allowing for a more comprehensive analysis of the results. A methodical seminar was held with the teachers of the experimental classes, during which they were introduced to the main purpose of research and experimental work and the basics of the technology of forming critical thinking in the process of educational activity of primary school children; as well as with the end-to-end application of the developed exercise system when studying all educational fields. During the formative stage of the experiment, teachers were also provided with the necessary methodological developments (in particular, the «Collection of exercises for the comprehensive formation of critical thinking in primary school children»), consultations and advice.

During the research and experimental work, we observed the following requirements: its implementation in natural conditions; observation of schoolchildren for a long time (one academic year); conducting measurements of the levels of primary school learners' critical thinking formation before and after the experiment.

To achieve the goal, a complex of empirical methods of scientific and pedagogical research was used: diagnostic (conversations, interviews, choice situations); observational (observation of the educational process, teacher observation of learners); prognostic (expert evaluation, criterion evaluation), experimental (study of the results of primary school learners' educational activities, pedagogical experiment); methods of mathematical statistics for processing experimental data to determine their significance and reliability. Statistical and mathematical calculations are automated using the Google Sheets cloud service. Qualitative and quantitative analyzes of the research results were used.

Research and experimental work consisted of the following main stages: ascertainment, search, formative and control.

The confirmatory stage of the experiment was conducted to find out the current state of critical thinking formation of primary school learners.

At the exploratory stage of the experiment, taking into account the data obtained from the ascertainment stage, a system of exercises was developed aimed at forming critical thinking in learners of primary education by means of an end-to-end approach. Criterion assessment of primary learners was also developed.

At the formative stage of the experiment, the proposed system of exercises was implemented directly across all educational fields.

At the control stage of the experiment, processing and analysis of the obtained data was carried out (comparison of control sections, expert evaluations of the formation of critical thinking before and after the research and experimental work; formulation of conclusions).

Results

In the developed system of exercises aimed at the formation of primary school learners' critical thinking, we distinguish target, substantive, procedural and effective components.

The target component includes the teacher's awareness and schoolchildren' acceptance of the end-to-end goal of the educational process in the conditions of NUS (New Ukrainian School) – the formation of primary school learners' critical thinking.

Content component – includes the content of the proposed exercises, aimed at forming signs of primary school learners' critical thinking.

The procedural component was represented by a set of exercises in action, which ensure the process of forming critical thinking of primary school learners by systematically and consistently conducting them in various subjects at primary school. Complexes of exercises were developed in accordance with the formation of each of the above-defined signs of critical thinking.

The effective component was characterized by the levels of formation of signs of critical thinking among learners of primary school.

Let's consider the exercises proposed by us for the formation of each of the identified signs of critical thinking of primary school learners in the conditions of the New Ukrainian School.

1. Exercises for the development of independence and autonomy of thinking of primary school learners: «Evaluation of arguments», «My position», «I think so», «Developing logic», «Positive and negative», «Critical analysis of a fact», «Find a generalization word», «Trap», «Arguments and facts», «Research and interpretation of the fact», «Search for characteristic features», «Analysis of the situation».

2. Exercises to develop resistance to suggestive influence: «Be careful», «Can a teacher be wrong?», «Reviewing a text», «Find a mistake of a friend», the game «Why-why», «Relationship between cause and effect», «Court on your own behalf».

3. Exercises for the development of self-criticism, self-reflection: «Evaluate yourself», «My contradictions», «My values», «My strengths and weaknesses», peer review of completed educational tasks, mutual characteristics, keeping columns in the diary «I like / I don't like», «I'm interested / I'm not interested.»

4. Exercises for the development of divergent thinking, insight: «Alternative questions», «How to understand?», «Surprise the class», «Reality or myth», «I am the character of the book», «Development of the plot (alternatives)», «Brainstorming (bank of ideas)», acting out situations by roles.

5. Exercises for the development of the ability to tolerant communicative interaction: «Discussion of conflict situations», «Consultative meeting of specialists», «Working together», «Discussion», «Debate», «Choice of argumentation», «Joint decision», «Teach others».

For the accuracy of the expert assessment data, we determined the levels of formation of critical thinking among learners for primary school (table 1).

In order to determine the influence of the exercise system on the formation of critical thinking among learners of primary school, we conducted an experimental test of its effectiveness.

At the beginning and end of the experiment, on the basis of the determined signs and levels, primary school teachers made an expert assessment of the formation of critical thinking in each schoolchild of the control and experimental groups by verification. Schoolchildren were offered to complete tasks developed in accordance with the signs of critical thinking and their findings. Namely: an essay on a given topic; the task of finding alternative solutions; the task of establishing causal relationships; the task of making an analogy (direct, fantastic, empathetic); ingenuity task; a series of questions «What is common and what is different?»; provocative questions and statements; task «Myth or reality»; analysis of the character, motives and actions of the characters of a particular book; task «Argue»; task «Evaluate yourself»; peer review, etc.

During the performance of the proposed tasks by schoolchildren, differences were observed in the course of thinking and behavior of the respondents of the control and experimental groups.

The total percentages of the distribution of primary school learners at the ascertainment stage of the study according to the level of formation of critical thinking in them by signs are presented in the table 2.

The analysis of the input data indicates an unsatisfactory level of independence of thinking and the ability to think independently of 4th graders. A high level was found in 10% (CG) and 9.52% (EG). However, a low level was demonstrated by the majority of respondents – 58.33% (CG) and 58.73% (EG). In the course of indirect observation at the lessons, it often happened that the teacher was waiting for the answer to the given question. And when the schoolchild expressed a judgment that differed from the opinion of the teacher, the latter often ignored it, not paying attention to the fact that there may be a rational thought in the statement. Therefore, a problem arose here: over time, schoolchildren get used to tricks, adapt to the teacher, answering as «it should be», getting used to refraining from expressing their opinion.

Table 1

Signs and their manifestations according to the level of formation of critical thinking of primary school children

Signs	Levels		
	High	Medium	Low
Independence and autonomy of thought	Reveals independence and self-sufficiency of thinking	Seeks to independently understand information; express an opinion when interested in the material.	Complete dependence on the opinions of others, timidity of expressing his/her own.
Resistance to suggestive influence	Demonstrates resistance to suggestive influence.	Stands up for an opinion if feels supported; able to notice the erroneous judgments of others; in some cases shows opposition to other people's opinions, but not always decisively.	Blind acceptance of information, ready conclusions, requirements, assessments of others.
Self-criticism, self-reflection	Shows a critical attitude towards oneself, the results of own activities.	Accepts the teacher's remarks about his/her own mistakes, but does not always listen to the opinions of his/her classmates.	Does not see one's own mistakes and shortcomings, cannot adequately evaluate own activities, has an inflated self-esteem.
Divergence of thinking, insight	Shows a desire to find optimal options for solving tasks.	If the teacher directs schoolchildren to a research activity, he/she takes part in it, but does not always show own initiative.	Passive thinking. Accepts standard, ready-made solutions to problems.
Ability to tolerant communicative interaction	Actively, confidently and tolerantly participates in communicative interaction.	Tries to justify his/her opinions and positions, but not always confidently and tolerantly.	In the process of dialogue, discussion, conversation, he/she is mostly silent.

Table 2

Level of formation of critical thinking in CG and EG (at the beginning of the experiment, in %)

Signs of critical thinking	Control group, %			Experimental group, %		
	High level	Medium level	Low level	High level	Medium level	Low level
Independence and autonomy of thought	10	31.67	58.33	9.52	31.75	58.73
Resistance to suggestive influence	8.33	35	56.67	9.52	33.33	57.14
Self-criticism, self-reflection	11.67	28.33	60	11.11	26.98	61.9
Divergence of thinking, insight	10	35	55	9.52	36.51	53.97
Ability to tolerant communicative interaction	13.33	40	46.67	12.7	41.27	46.03

(Source: calculated by the authors on the basis of data)

It was found that such a sign of critical thinking as resistance to suggestive influence was poorly developed in 4th grade schoolchildren. A low level of formation was demonstrated by 56.67% (CG) and 57.14% (EG) of respondents. In our opinion, this is connected with the age characteristics of primary school children, who are mostly oriented towards authorities. It is still difficult for them to consistently follow the answers of others during the lesson and to find errors in their statements and actions. If mostly primary schoolchildren see the mistakes of their peers, they often do not see them, or are afraid to see them in adults. Accordingly, if schoolchildren can still disagree with their peers, then they do not dare to resist the demands, statements of adults, without thinking about the reasons. And teachers do not always support children's resistance to the suggestion of other people's opinions.

In our research, self-criticism and self-reflection among primary schoolchildren were also found to be insufficiently developed. A high level was demonstrated by 11.67% (CG) and 11.11% (EG), an average level – 28.33% (CG) and 26.98% (EG), a low level – 60% (CG) and 61.9 (EG) of respondents. Adequate self-esteem remains a significant problem for schoolchildren with a critical attitude towards themselves. When evaluating classmates, they rarely compare their actions and deeds with their own. They evaluate themselves not as strictly as their peers. It is also more difficult for child leaders to admit that someone is achieving better results than they are. Accordingly, this was reflected in the communicative interaction of schoolchildren. The analysis of expert evaluations showed that primary school learners do not know how to humanely treat the opinions and suggestions of others, as well as tolerantly cooperate with others to achieve a common goal. The table shows that learners with a high and medium level of development have few signs of critical thinking, and learners with a low level of development prevail. Although the measurement of the ability to tolerant communicative interaction showed slightly better results than the previous signs. However, there are also many learners with a low level of development: 46.67% (CG) and 46.03% (EG).

There is a small percentage of schoolchildren with a high level of formation of divergent thinking (10% – CG and 9.52% – EG). Although by nature the thinking of primary schoolchildren is still devoid of stereotypes, they develop creativity, imagination and fantasy (no wonder there are so many fantasists at this age), but still we have disappointing data.

It can be seen from the table that learners with a high and medium level of formation of signs of critical thinking are few, schoolchildren with a low level of development prevail.

The results of the expert evaluation of the development of critical thinking signs in the control and experimental groups became the basis of the organization of experimental research work on the development of critical thinking, improving the content and methodical support of the educational process.

Research-experimental work with learners of primary school of the experimental group was carried out according to the experimental model developed by us. At the same time, we assumed that the systematic and end-to-end application of a complex of exercises can contribute not only to the conscious perception of the content of the material, but also ensure the formation of critical thinking of learners. We did not aim to rebuild the curriculum, we sought to strengthen the work of the teacher by means of a system of developed exercises, applying an end-to-end approach to increase the level of formation of critical thinking of primary school children.

As the results of the formative stage of the experiment showed, the systematic use of exercises aimed at the formation of critical thinking at the lessons led to certain shifts in this direction in the learners of the experimental group. At the control stage of the experiment, using a similar method, we once again carried out an expert assessment of the formation of critical thinking of the learners. The generalization of the results of the expert assessment allows us to conclude that the practical application of the exercises developed by us largely ensured the achievement of optimal results in the formation of critical thinking of learners of primary school (table 3).

Table 3

The level of formation of critical thinking among learners of primary school CG and EG (at the end of the experiment in %)

Signs of critical thinking	Control group, %			Experimental group, %		
	High level	Medium level	Low level	High level	Medium level	Low level
Independence and autonomy of thought	13.33	33.33	53.33	28.57	53.97	17.46
Resistance to suggestive influence	11.67	38.33	50	25.4	52.38	22.22
Self-criticism, self-reflection	15	30	55	30.16	49.21	20.63
Divergence of thinking, insight	13.33	38.33	48.33	19.05	41.27	39.68
Ability to tolerant communicative interaction	16.67	43.33	40	31.75	50.79	17.46

(Source: calculated by the authors on the basis of data)

The analysis of expert evaluations regarding the development of critical thinking in primary school students in CG and EG before and after the experimental study enables us to derive qualitative conclusions.

It should be noted that by developing independence of thinking, the desire to independently interpret educational and other information, the respondents of the experimental group became more active in expressing their own opinions on the issues under consideration. However, the problem of forming the ability to critically analyze the validity of certain statements of teachers and other adults has not been sufficiently resolved. Although at the end of the experiment, the number of schoolchildren with an average level was 53.97%, and, as a rule, schoolchildren show more features of this characteristic, such as the ability to actively express their own thoughts.

It should be noted that it is difficult for primary school learners to resist suggestive influence. Although the overall percentages of a high level of formation of this characteristic in EG increased to 25.4% (against 11.67% in CG), however, even these schoolchildren cannot always express their disagreement with the opinions of others, if they even notice their fallacy. The number of children who sought to understand the reasons for certain phenomena, sayings, and statements increased.

As we can see, the number of schoolchildren who have learned to see their own mistakes and adequately treat them increased. Schoolchildren carefully perceived the comments of teachers and peers about their mistakes, learned to admit that other learners coped with tasks better than them. The number of children with a high level of development of this characteristic increased in EG to 30.16% (against 15% in CG), but they also sometimes hesitated to assess their own knowledge and behavior in specific situations, sometimes even underestimating their own assessment.

Divergence of thinking among primary schoolchildren also increased. It should be noted that in EG the number of children with a high level increased to 19.05% (versus 13.33 in CG). At the end of the experiment, the number of learners with an average level of development of this characteristic prevailed (41.27%). As the observation showed, it was difficult for younger learners to question the received information. They still had a prevailing trust in the authority of adults, books, television, and the Internet. Primary schoolchildren do not always seek to independently understand the correctness of solving educational tasks. However, the number of children who saw alternative solutions increased, sought to find their own solution to the problem, to offer their own way, their vision of overcoming educational difficulties.

In the process of research and experimental work, the level of development of children's ability to participate in communicative interaction increased. Some of them began to try to argue their opinions, listen carefully to others and seek agreement with their comrades in controversial situations. The number of children with a high level of development of this trait increased to 31.75% (against 16.67% in CG). They began to listen more carefully to other opinions, restrain their emotions in discussions. The use of appropriate exercises taught children to cooperate with each other in pairs and groups, and their communication skills improved. Schoolchildren began to better understand the essence of the educational material, to be more interested in the surrounding events and phenomena.

Let us present generalized data obtained as a result of comparing the state of critical thinking formation in primary school children in the control and experimental groups at the beginning and end of the experimental work (table 4). To do this, we calculated the average percentage of development of all the signs we determined in schoolchildren who participated in the experiment. Then the percentages sum of each of the signs development according to a certain level was calculated and this number was divided by five. As a result, we received the following data.

Table 4

Levels of primary school learners' critical thinking formation at the beginning and end of the experiment (summarized data)

Groups	Number of learners	High level		Medium level		Low level	
		At the beginning (%) At the end	At the end (%)	At the beginning (%) At the end	At the end (%)	At the beginning (%) At the end	At the end (%)
CG	60	10.67	14.00	34.00	36.66	55.33	49.33
EG	63	10.47	26.99	33.97	49.52	55.55	23.49

(Source: calculated by the authors on the basis of data)

It is gratifying to note that the number of learners with a high level of critical thinking in the experimental group increased by 16.52%, in the control group – by only 3.33%. With a low level of development of critical thinking, the number of learners in the experimental group decreased by 32.06%, in the control group by 6%.

Discussion

The analysis of the study results allows us to state that although the number of schoolchildren with an average level of critical thinking formation prevails in the experimental group (which is connected with certain age characteristics of schoolchildren), the number of schoolchildren with a high level of critical thinking formation in EG is greater by 12.99% against the number of schoolchildren in CG, with an average level of development – by 12.86%, and with a low level – by 25.84% less than in CG.

This confirms the hypothesis of the study that the ability of primary school learners to think critically, defined by the State Standard of Primary School as a cross-cutting one, can be successfully formed according to the approach of the same name.

The findings of this study indicate that the cross-cutting approach significantly contributes to the formation of critical thinking skills among primary school learners. These results align with previous studies emphasizing the importance of integrating interdisciplinary strategies in primary education. For instance, a study by Davies et al. (2022) demonstrates that interdisciplinary teaching methods enhance critical thinking and problem-solving abilities in elementary primary school learners, providing empirical support for the effectiveness of cross-cutting approaches.

Comparing our results with existing literature, it becomes evident that critical thinking development in young learners requires a holistic approach that combines traditional subject-based learning with problem-solving and reflective activities. Unlike studies that primarily focus on a single-discipline method, our research highlights the necessity of cross-subject interactions in fostering higher-order thinking skills. Additionally, we observed that the engagement level of primary school learners increased when critical thinking tasks were embedded within different disciplines, supporting the notion that meaningful learning occurs when knowledge is interconnected. Recent research by Lee and Anderson (2023) underscores the importance of teacher scaffolding in developing these skills, a factor that our study also identified as crucial for successful implementation.

Despite the promising findings, this study has certain limitations. First, the research was conducted within a limited number of schools, which may affect the generalizability of the results. Future studies should consider expanding the sample size to include diverse educational settings. Second, the assessment of critical thinking development relied on qualitative methods, which, although insightful, might benefit from additional quantitative measures to enhance objectivity. Moreover, longitudinal studies could provide deeper insights into the long-term impact of the cross-cutting approach on learners' critical thinking abilities. Another limitation is the lack of analysis on the potential impact of digital learning tools in this approach, which is an increasingly relevant aspect given the rise of technology-enhanced learning environments. Research by Smith et al. (2024) suggests that integrating digital tools in interdisciplinary teaching can further enhance critical thinking skills, indicating a potential avenue for future exploration.

In light of these limitations, future research should explore how digital tools and emerging educational technologies can further enhance the cross-cutting approach. Additionally, investigating teacher training programs on interdisciplinary teaching methodologies could offer valuable insights into how educators can effectively implement these strategies in various educational contexts. Further research could also examine how social and economic factors influence the effectiveness of cross-cutting approaches in different school environments.

Overall, this study contributes to the growing body of literature on critical thinking development in primary education and underscores the importance of interdisciplinary teaching strategies. By addressing the highlighted limitations and expanding upon the research scope, future studies can continue to refine and optimize methods for fostering critical thinking among young learners.

Conclusions

The analysis of expert assessments from the final evaluation of experiment participants confirms the effectiveness of the chosen methodological approach and the implemented system of exercises designed to actively develop critical thinking in primary schoolchildren.

Thus, we come to the conclusion that purposeful work and an end-to-end approach in the educational process to the formation of primary school learners' critical thinking ensures the following positive changes:

– the cognitive interest of schoolchildren, their activity in solving assigned tasks increases;

- the desire of schoolchildren to carefully interpret the received information, instead of ready perception of it, increases;

– there are positive changes in the critical attitude towards one's own activities, in the desire to critically evaluate the received information, the actions of others, etc.;

- search orientation of thinking increases, insecurity, inferiority complex and fear of making a mistake disappear;

- fear of disagreeing with others, «blind» following the opinions of others decreases;

- attempts to listen carefully to other views, to jointly search for alternative ways of solving the problem, etc. increase.

Thus, the hypothesis formulated at the beginning of the research was confirmed. The results of the experimental work showed that the age characteristics of the primary school learners allow them to form signs of critical thinking. It is more effective if the researched technology is applied systemically and end-to-end. Also, the successful application of critical thinking technology depends on the teacher's awareness of one's mission in the educational process. There should be equal interaction between the participants of the educational process, everyone has the right to express their position and be heard. End-to-end implementation of the technology of critical thinking by means of a complex of exercises makes it possible to form a modern competitive, successful and adapted to the changing conditions of today's young generation. However, for this, it is necessary to carry out a fundamental end-to-end renewal of psychological and pedagogical approaches in the organization of the educational process at primary school.

The findings of this research confirm that the cross-cutting approach to critical thinking development in primary school learners is effective when applied systematically. The study highlights that age characteristics of young learners enable the formation of critical thinking skills, which are further enhanced by the teacher's awareness of their role in the educational process and the establishment of equal interaction among participants. The research implies that for modern education to foster a competitive, adaptable, and successful young generation, it is essential to implement a fundamental, end-to-end renewal of psychological and pedagogical approaches in primary school education. These insights contribute to the broader discourse on educational reform, emphasizing the necessity of structured and integrated methodologies in cultivating essential cognitive skills.

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Implementation of Online Teaching in Primary Schools During the First Lockdown in Greece: Teachers' Views

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Abstract

The COVID-19 pandemic brought about significant changes in education, with online teaching emerging as the primary means of teaching. The rapid transition to the digital world has been a significant challenge for teachers and students. This research focuses on primary school teachers' views on online teaching in Greece during the first lockdown. The study examines student-student and student-teacher interaction during online teaching, along with the benefits, challenges, and suggestions for improvement. The research is based on interviews with 15 teachers. The survey findings indicate that there was interaction between teachers and students while there was no interaction between students. The advantages of online teaching were highlighted as continuity of the teaching process, psychological support for students, development of new skills and enhancement of students' autonomy. On the other hand, the disadvantages included technical issues, insufficient teacher training to reinforce existing social inequalities, and the emergence of new forms of inequalities. In order to improve online teaching, it is proposed that teachers and students be trained, the equipment and infrastructure of schools be improved, and online teaching platforms be upgraded.

Keywords:

Online Teaching; COVID-19; Primary School; Teachers; Education Policy

Introduction

The COVID-19 pandemic has brought about significant changes worldwide, posing new social, economic, medical and educational challenges (Nicolau et al., 2020). In education, COVID-19 has brought about drastic changes, with online teaching emerging as a critical factor in the continuity of the educational process (Masali & Kougiourouki, 2022; Thanos et al., 2023). The introduction of online teaching during the pandemic period, both in Greece and internationally (Doz & Doz, 2023; Evangelou, 2022), was an unprecedented challenge (Kim & Asbury, 2020), with teachers facing the need to adapt immediately to a new reality, where teaching moved from the classroom to the digital world (Thanos et al., 2023). The forced transition to online teaching has been accompanied by multiple challenges, including the lack of a carefully designed educational framework (Lansangan et al., 2022). However, despite these challenges, online teaching has established

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itself as a new reality (Masali & Kougiourouki, 2022), offering a promising future for education and inspiring hope among teachers, parents and students (Garbe et al., 2020; Hammerstein et al., 2021; Kim et al., 2021).

The purpose of this study is to examine the views of teachers of primary schools in Greece regarding implementing online teaching during the first lockdown imposed due to the COVID-19 pandemic. The research questions of the study are as follows:

1. How do primary school teachers perceive the level of student-student and student-teacher interaction during online teaching?
2. What advantages and disadvantages do primary school teachers identify in the online teaching approach implemented during the lockdown?
3. What suggestions do primary school teachers offer for improving online teaching in future implementations?

COVID-19

The COVID-19 pandemic, an unprecedented global health crisis that emerged in December 2019 in Wuhan, China (Wilder-Smith & Freedman, 2020), has become the largest of the 21st century (Chu et al., 2020). The novel SARS-CoV-2 coronavirus, the culprit behind this disease, has swiftly spread across the globe, sparking severe concerns in the international community. On 30 January 2020, the World Health Organization declared COVID-19 a public health emergency as infections and deaths surged worldwide. By January 2024, an estimated 770 million infections and over 7 million deaths have been reported (WHO, 2024).

The threat of this disease has led governments worldwide to take drastic measures to limit the spread of the virus. One of the measures several countries took, where cases were increasing rapidly, was the lockdown of citizens to reduce interaction between them (Davies et al., 2020). To achieve this, governments decided, among other things, to work from home, close territorial borders and some businesses that were not considered essential, and suspend schools at all levels (Wilder-Smith & Freedman, 2020). The decision to close schools was based on uncertainty about the risks of the virus to children and the assumption that children may act as significant vectors of the disease (Christakis et al., 2020). UNESCO reports that more than 1.5 billion students worldwide were affected by school closures (UNESCO, 2023).

In Greece, the response to the COVID-19 pandemic included significant adjustments to daily life and the educational process. On 23 March 2020, a curfew was decided for residents and was only allowed in exceptional cases (Government Gazette 986/B/22-3-2020). Prior to this, on 10 March 2020, the suspension of the face-to-face educational process had already been decided, which lasted until May 2020 (Government Gazette 783/B/10-3-2020; Government Gazette 2026/B/27-5-2020). During this period, with the school units closed, it was decided that online teaching would be provided synchronously and asynchronously (Thanos et al., 2023). Online teaching, which until then was mainly applied to adults (Kalogiannakis et al., 2009), was extended to all educational levels due to the pandemic (Giavrimis & Ferentinou, 2021). In primary education, face-to-face teaching was reintroduced on 1 June 2020 and completed on 26 June of the same year (Government Gazette 2026/B/27-5-2020; Government Gazette 111 A/12-6-2020).

Online teaching and its implementation during the COVID-19 period

Online teaching is a type of educational process that takes place without the physical presence of the learner (Gentes & Cambone, 2013; Lionarakis, 2001a) who self-regulates his/her learning, removing any spatio-temporal limitation (Sofos et al., 2015). The learner follows a heuristic path of self-education and is activated under the guidance of a teacher-counsellor. As a multimodal and flexible educational process, online teaching works autonomously or complementarily to meet the unique educational needs of students who cannot attend face-to-face classes and utilise readily available and accessible educational materials (Gentes & Cambone, 2013). It usually serves adults wishing to expand their knowledge, and minors are often absent from school for health reasons (Vassala, 2005).

When implementing online teaching, the student masters new knowledge by operating with more autonomy, experientially and through discovery. One of the main factors that contribute to the implementation of online teaching is the organisation of teaching and the selection of appropriately designed educational material (Lionarakis, 2001a), which is required to follow pedagogical standards and has a supportive role. Thus, the learner is guided in his/her study and his/her interaction with the educational material is enhanced. Through feedback processes on his/her learning path, the learner is assessed, reinforced and encouraged in his/her progress (Manousou, 2008).

According to Lionarakis (2001b), flexibility and interaction characterise all the stakeholders, processes, and means of online teaching (student, teacher, learning, teaching, communication, teaching materials, place, time, educational institution, and assessment), giving them versatility.

The first attempts to implement online teaching were made by universities in New Zealand and Australia, which, from 1890 onwards, provided online teaching

curricula (Sofos et al., 2015). Therefore, it is not a modern educational method, but compared to the past, it is differentiated in how it is implemented, and in the practices applied. In the past, online teaching was carried out through mail, then it was based on audio and video tapes, and later on telephone communication, while today, it is mainly carried out through the Internet (Vassala, 2005). Thus, the distance is bridged thanks to modern technological means that offer two-way communication between the learner and the teacher (Gelameris, 2015; Moore & Kearsley, 2012).

Abroad, it is widespread, and the trend is permanently increasing in developed countries where it is utilised to enrich the educational opportunities of learners qualitatively and in developing countries where it is used to combat illiteracy more economically (Kokkali & Georgiadi, 2009). Virtual schools that operate provide autonomous online teaching and constitute a dynamic and evolving educational space, especially in sparsely populated areas where the geographical distribution of the population dictates similar practices. In these cases, the initial cost of equipment and access to the educational environments are entirely covered by state funding (Kokkali & Georgiadi, 2009; Miminou & Spanaka, 2013). When online teaching is used abroad in a complementary way, it is done selectively, even without special reasons to impose it, to increase the educational opportunities of learners, for example, for gifted students to acquire higher-level knowledge earlier or to acquire information and technological literacy and prepare them for lifelong learning (Gimisis & Apostolakis, 2011).

Only when the outbreak of the global coronavirus pandemic in Greece in March 2020 was no generalised online teaching offered, neither stand-alone nor complementary. In isolated cases by researchers or private schools, there was limited implementation of supplementary school online teaching programmes. Although the global data were excellent and the Greek experimental data were encouraging, the official state needed to be faster to promote institutionally similar practices, mainly for financial reasons (Koutzeklidou & Mavroeidis, 2017). It restricted innovative actions to asynchronous educational environments, which are learning environments where students and teachers are not required to be online at the same time, which enhanced educational opportunities but lacked flexibility and interactivity. The increased interest of teachers in similar distance collaboration programmes is evident from the enthusiastic support of the European community of schools through the secure pedagogical platform of 'eTwinning' (Paleodimou, 2017).

The situation changed radically with the health crisis that imposed online teaching to reduce the spread of the coronavirus and forced the educational community to adopt synchronous and asynchronous online teaching practices so as not to remove students from the learning processes. By registering in the Panhellenic School Network and obtaining personal passwords (Thanos et al., 2023), minors and adult students had access to digital environments created for educational purposes (e-me, e-class, Webex) (Masali & Kougiourouki, 2022).

During the three months of implementation of online teaching in Primary Education in Greece, many problems emerged, the main ones being the lack of available electronic media by a large number of teachers and students, lack of relevant training, various technical problems in connecting and participating in lessons, issues of personal data protection and privacy of teachers and especially of underage students (Thanos et al., 2023). The protests were constant, but at the same time, the diligent efforts made by most of the educational community, who, despite the surprise, worked tirelessly, paid off, and about 400,000 e-class courses were created, some of which were open and freely accessible, others required simple registration in the Panhellenic School Network. Others were closed and offered only to specific students (www.sch.gr).

The role of student interaction in online teaching

A key aspect of primary education is the interaction between students and teachers, which plays a crucial role in cognitive, social, and emotional development (Pianta, Hamre, & Allen, 2012). Through social interaction, students cultivate communication skills, collaboration, and self-regulation, while also constructing knowledge through dialogue and peer engagement (Vygotsky, 1978). In traditional classroom settings, learning is facilitated through structured discussions, group activities, and cooperative problem-solving (Wentzel & Miele, 2016).

However, the absence of direct interpersonal interaction in online learning environments poses significant challenges, particularly for young learners who are at a critical stage of their socio-emotional development (Moore, 1997). Studies indicate that reduced student interaction in virtual settings can lead to feelings of isolation, decreased engagement in the learning process, and lower academic performance (Borup et al., 2014). Furthermore, the lack of non-verbal cues and immediate feedback in digital instruction may hinder communication between teachers and students, negatively impacting the learning experience (Xie, Heddy, & Greene, 2019).

The COVID-19 pandemic exacerbated these challenges, as the abrupt transition to remote learning left students and educators unprepared to address the consequences of limited interaction (Moorhouse & Wong, 2021). Although digital platforms such as Webex and Zoom attempted to replicate face-

to-face communication, their effectiveness varied among students, particularly in early childhood education (Reich et al., 2020). The inability to facilitate spontaneous discussions and peer-to-peer collaboration further intensified these difficulties, highlighting the critical role of interaction in fostering meaningful and effective learning experiences.

Digital divide for teachers

The potential of new technologies in education is immense, offering opportunities to build knowledge and cultivate skills. These dynamic and interactive audiovisual media provide engaging learning experiences based on personal exploration, collaboration, and interaction. Learners are exposed to new forms of literacy (technological, multimodal, and critical) that are powerful tools for meeting contemporary demands (Gelameris, 2015).

Online teaching is now feasible and accessible, thanks to new technologies provided by modern online and interactive multimedia. The increased possibilities of e-learning in modern pedagogical environments support the conventional educational system at all levels and, in addition, open up avenues for further education in many fields of knowledge (Manousou, 2008). The philosophy of online teaching is based on providing equal opportunities to all those interested in gaining flexible access to knowledge (Vassala, 2005), and by overcoming the constraints of formal education, it provides expanded opportunities for learning and democratisation of knowledge. At the same time, it enhances lifelong learning (Manousou, 2008). It professes to intensify knowledge and increase learning opportunities for those who seek it at every stage of their lives through open courses at every level provided free of charge online by accredited institutions. Thanks to direct, permanent and uninterrupted access to the educational material of online teaching, characterised by interactivity, versatility and pedagogical design, learning opportunities are multiplied (Vassala, 2005).

Integrating technologies in the educational process enhances the quality of learning (Camilleri et al., 2014; Kalogiannakis & Kalkanis, 2018). Many teachers adequately meet the increased demands (Kelpanidis, 2004) by adopting innovative practices and integrating technologies into their teaching (Lionarakis, 2017; Polydoros, 2017; Somekh & Lewin, 2005). However, a percentage of teachers face difficulties in adopting digital technologies due to a lack of training or technophobia (Tassie, 2014; Anastasiadis, 2020). In Greece, teacher training in new technologies remains fragmented (Anastasiadis, 2020).

During the COVID-19 pandemic, the digital divide among teachers became more pronounced, as online teaching requires specific skills and resources (Camacho et al., 2020; Reed, 2020). In Greece, inadequate training and underfunding of public education affected teachers' ability to adopt new technologies (Anastasiadis, 2020), reinforcing social inequalities among students (Sachinidis & Polychronakis, 2009). To address these challenges, it is necessary to strengthen teacher training and financial support for access to digital technologies (Anastasiadis, 2020).

Methodology

Research Design

This study adopts a qualitative research approach to explore the experiences of primary school teachers regarding online teaching during the COVID-19 pandemic. Specifically, a phenomenological research design was employed, as this method enables an in-depth understanding of participants' lived experiences (Creswell, 2013). The phenomenological approach was chosen because it allows for an exploration of teachers' perceptions, challenges, and strategies in adapting to online learning environments.

Instrument

Data collection was conducted using semi-structured interviews, which provided flexibility in exploring teachers' views while ensuring consistency across participants (Kvale & Brinkmann, 2009). The interview guide included open-ended questions designed to elicit detailed responses regarding the challenges, benefits, and interaction patterns in online learning. Some sample questions included:

1. How would you describe your experience with online teaching during the lockdown?
2. What were the main challenges you faced in ensuring student engagement and interaction?
3. What strategies did you use to maintain student-teacher and student-student interaction?

Participants

The study involved 15 primary school teachers from various schools across Greece, selected through purposive sampling to ensure a diverse range of perspectives. Participants had varying levels of experience with online teaching, allowing for a more comprehensive analysis of the challenges encountered. Informed consent was obtained prior to participation, and anonymity was ensured throughout the research process.

A summary of participants' demographic information is presented in Table 1:

Table 1:
Participants' Demographic Information

ID	Gender	Specialty	Years of Teaching Experience	School Location
P1	Female	Teacher	22	Semi-Urban
P2	Male	Teacher	5	Rural
P3	Female	Teachers of specialist subjects	7	Rural
P4	Female	Teacher	18	Urban
P5	Female	Teacher	20	Urban
P6	Female	Teacher	12	Rural
P7	Male	Teachers of specialist subjects	13	Semi-Urban
P8	Male	Teacher	10	Rural
P9	Female	Teacher	14	Semi-Urban
P10	Female	Teacher	13	Urban
P11	Female	Teachers of specialist subjects	16	Urban
P12	Male	Teacher	6	Rural
P13	Female	Teachers of specialist subjects	3	Urban
P14	Female	Teacher	11	Semi-Urban
P15	Male	Teachers of specialist subjects	9	Rural

Data Collection and Analysis

Data were collected between May and June 2020 through semi-structured interviews, which were conducted both in-person and remotely via Webex. The choice of format depended on participants' availability and accessibility.

Participants were asked to describe their experiences with online teaching, the challenges they encountered, and their strategies for maintaining student engagement and interaction. The interviews lasted between 45 to 60 minutes and were audio-recorded with participants' consent for accurate transcription and analysis.

The data were analyzed using thematic analysis (Braun & Clarke, 2006), following a systematic coding process:

1. Familiarization with data: Initial reading and re-reading of transcripts.
2. Generating initial codes: Identifying recurring concepts and categorizing key themes.
3. Searching for themes: Grouping related codes into broader themes.
4. Reviewing themes: Refining themes based on relevance and frequency.
5. Defining and naming themes: Establishing clear thematic categories to present findings.

Reliability and Validity Considerations

To ensure credibility, the study employed triangulation by comparing teacher responses across different school settings. Member checking was also conducted, allowing participants to review and confirm the accuracy of their responses. Additionally, peer debriefing was used to enhance the reliability of data analysis, ensuring that findings were not influenced by researcher bias (Lincoln & Guba, 1985). Finally, a rich, thick description of findings was provided to enhance transferability and contextual understanding.

Results

This section presents the findings of the study, reflecting the perspectives of the participating teachers. The results are categorized into key thematic areas:

a. the level of student-student and student-teacher interaction during online teaching,
b. the advantages and disadvantages of online teaching, and
c. teachers' suggestions for improving online teaching.

Table 2:
Thematic Categorization of Teachers' Perspectives on Online Teaching

Thematic Category	Subthemes
Interaction in Online Teaching	• Limited student-student interaction due to restricted two-way communication. • Student-teacher interaction mainly through digital platforms
Advantages of Online Teaching	• Ensuring continuity and maintaining communication. • Psychological support and sense of belonging. • Development of IT skills and student autonomy.
Disadvantages of Online Teaching	• Lack of personal interaction and pedagogical climate. • Technical difficulties and lack of training. • Absence of a unified policy and delayed guidelines. • Reinforcement of social inequalities.
Teachers' Suggestions for Improving Online Teaching	• Teacher training on online teaching and technical skills. • Student training to develop digital literacy. • Upgrading school infrastructure and online platforms. • Ensuring equal access to technological equipment and internet.

To provide a structured overview of the findings, Table 2 provides a summary of the key thematic categories and subcategories identified through the analysis.

Student-Student and Student-Teacher Interaction during Online Teaching

Regarding student-student interaction during online teaching, some teachers reported that 'it does not exist', primarily due to the limited possibility of 'two-way communication' through 'digital platforms'.

> *I have not found this to be the case. I do not believe it exists (P-1).*
>
> *Not among the students. I even built a wall in the e-class but did not see any interaction between them. I need to find out between them, of course, with messages if they communicate. However, from the beginning, when I had talked to some of them and I was looking for some others to find them to put them on the platform, I asked them if they had talked to these students, and they told me they had not talked at all (P-2).*
>
> *No, there is not (P-6).*
>
> *The interaction between my students during online teaching is much less than in formal teaching. Opportunities for two-way communication are reduced, and communication is often limited to more structured and formal forms through digital platforms (P-13).*

However, some teachers observed some degree of student-student interaction during online teaching.

> *Of course, there is. I see that the children are having some conversations through chat, which Webex enables them to do. When I see that they are misbehaving, I close the chat completely. They interact, but I do not want the children to talk to each other in the delivery because the essence is lost... (P-7).*
>
> *In the comments, they often respond to each other, i.e. there is interaction between them (P-5).*

Regarding student-teacher interaction, several teachers stated that they maintained communication with students primarily through 'digital platforms'.

> *There is interaction. I do not ask them to send me the papers so I can correct them. I do not get into that part because I see it more as a review, and I do not want to stress them out. There is interaction mainly through e-class, where they send me messages and say sir, we liked this; we did that exercise... Some also sent me corrected assignments in Email (P-1).*
>
> *It exists with 70% of the students (P-15).*
>
> *Yes, on Webex, it did not exist before (P-4).*
>
> *Yes. We have the messages that we communicate within the platform. Because the answers uploaded on the platform are often given in the comments, there is also interaction (P-5).*
>
> *Of course, there is, especially in modern education (P-9).*

On the other hand, some teachers did not observe any student-teacher interaction during online teaching.

> No, there is no interaction. In the e-class, I did some exercises, and once the student completed them, he got direct feedback on whether he had done well. However, basically, there is no interaction between the children and me, although I am open and tell the parents that whatever they need, I am here (P-7).

Advantages and disadvantages of online teaching

According to the participants' responses, online teaching, as an emergency response to the challenges of the first lockdown due to the COVID-19 pandemic, presented both advantages and disadvantages during its implementation in primary schools in Greece.

Advantages

Some teachers highlighted the benefits of online teaching, emphasizing its role as a 'safe' means of ensuring continuity in the teaching process while also allowing for the maintenance of communication between students and teachers. Additionally, online teaching was perceived as offering psychological support to students and reinforcing their sense of 'belonging to a group'.

> *I believe that it is a way to protect ourselves from the pandemic and maintain communication with our students. It provides health security and maintains communication (P-1).*
>
> *Children's contact and their psychology (P-3).*
>
> *The students keep in touch with their teacher. They may feel that they belong to a group. Let me tell you I made sure to make them feel that way through some pictures that I would send them that we had taken in the classroom and tell them we continue to be a team (P-15).*
>
> *The children are in contact with us; they feel close to us, that we are here, we exist, and we try to reach them somehow. Since Wednesday, we have been instructed that we have the right to move on to the curriculum. That is, there is more focus on the subject matter, which interests them and piques their interest more because the character before was more repetitive (P-13).*
>
> *The first advantage of online teaching is that it keeps the student in touch and communication with the learning teacher. This is the most important thing; this is what we are interested in (P-10).*

Another significant advantage of online teaching, according to some teachers, was that it enhanced students' IT skills and encouraged greater autonomy in their learning, as they had to adapt to a new digital learning environment.

> *The children were forced, I do not know how much*

help the parents were, to read the pronouncements of the exercises. Even what they write in Word sometimes builds computer skills. However, I must tell you that they read the pronunciation. In the past, for example, I used to give them an exercise, and they would ask me directly what to do in the exercise without reading the pronunciation. They are slowly being forced to read the pronunciation themselves because they do not have me around. For example, in one exercise I had them do for writing production, I told them to write a fictional story without anyone asking me what story. Whatever story they wanted, as long as it was fictional... At first, they asked me what we should do here and there... I told them to try more independently, and they had to think further. I think online teaching has excellent benefits but is complementary (P-2).

The advantages of the whole process for me are that I feel that I learned some things more that I wouldn't have learned if I didn't need to. I also feel that the kids are starting to gain other skills that I didn't expect from second graders. That is the responsibility and responsiveness that they showed (P-4).

The whole process has the advantage that we would only be learning some of these platforms like E-class if this was happening. Why do we have to get to all of this and be forced to find out on our own what we can do? (P-5).

Children are getting more into the e-learning process because, slowly, both in high school and at university, everything will be done by computers. They are getting into a typing process of dealing with the computer, not just for play. Children are being forced to see the computer as a learning tool in addition to play. In order to learn, I can use new technologies (P-7).

Disadvantages

Despite its benefits, teachers identified several disadvantages of online teaching. Many reported that online teaching is 'impersonal' and lacks direct human 'contact', making it difficult to establish a 'pedagogical climate', which they considered essential for effective learning. Consequently, they argued that online teaching 'cannot replace face-to-face teaching'.

The disadvantage is that it is impersonal; there is no physical presence, no physical contact, and no pedagogical climate, which is very important. There is no immediacy (P-1).

There is no immediacy in the classroom. There is no exchange of thoughts and feelings, sharing, bonding, or pleasant classroom atmosphere with jokes and all that comes with everyday contact with students. That element is missing, which is very important. It keeps us at a distance. Bridging that gap is different from our face-to-face teaching with the kids. Online teaching cannot replace face-to-face teaching (P-10).

There needs to be contact and interaction in the classroom. You can use humour and talk about a topic in general. It is different in the classroom (P-14).

Other teachers highlighted technical issues as a major drawback, emphasizing that the digital 'platforms' did not function properly, and both teachers and students lacked adequate training to navigate online learning environments. This problem was especially challenging for 'weaker students' and 'students with special educational needs', who faced increased difficulties in engaging with online learning.

Teachers needed to be adequately trained in distance teaching (P-13).

Apart from the fact that the platforms were not working, the students were not familiar with using the platform, so they definitely had to have help from parents. Those who could not get help from parents could not get in (P-6).

There are disadvantages. Mostly for, weaker students who cannot use the new technologies on their own, they also need the help of someone older. Moreover, for some pupils, for example, with learning difficulties or special educational needs, you need help to reach them well at a distance. Children with autism who do not have much verbal skills see you on camera, you ask them questions, and they do not answer you. In-person, it would be easier (P-7).

The teachers needed to be adequately trained, the online platforms did not support such many users, and the children needed to be more familiar with such platforms. There were many difficulties (P-8).

Additionally, teachers criticized the 'absence of a unified policy' and the delayed guidance from the Ministry of Education, which created 'confusion' and 'stress' and hindered the effective implementation of online teaching.

Another disadvantage of online teaching is that the Ministry did not provide a formal policy for us. Clarifications took a long time to come, making the whole process even more difficult (P-6).

Direction and guidance were needed to conduct our Webex lesson (P-4).

Too many. First, they must tell us the existing legal framework because we do not know it. Does it exist? If there is no legal framework, what are we talking about? They should tell us what is pedagogically correct. Tell us what is being done at each level. Are all levels the same? Shouldn't someone from the Ministry tell us what we should do responsibly? So all of this should have a legislative framework, goals, objectives... So that we know how to operate it (P-13).

It was sudden, and it made us nervous, and the most damaging thing I think is that there was no standard line for all schools and as a result parents were calling and saying in this school they are doing a modern one, are you going to do it? In that classroom, they put this up. Are you going to do it? One school started the whole process earlier than the other. So there had to be a standard line for all schools so that we all work the same way and everything was clear (P-15).

Another disadvantage of online teaching, according to some teachers' views, was 'reinforcing existing social inequalities' and 'creating new forms of inequalities'. In particular, it was pointed out by the teachers that 'the lack of appropriate logistical infrastructure' led to reduced access to educational materials and difficulties in communicating online, negatively affecting learning for some, while other students

with better 'access to technological resources' had a relative 'advantage'. In addition, the situation was highlighted as being aggravated for students from vulnerable social groups, non-speakers of Greek or families with a low level of education, presenting specific difficulties in accessing and participating in online teaching.

> *I think that online teaching has contributed to the reproduction of social inequalities to a very large extent-much more than any other form of education—because there are parents and children in particular who are de facto excluded, and this has been shown in practice (P-1).*
>
> *To a certain extent, it contributes to the reproduction of social inequalities. For example, I told you that one student didn't have a computer, and another student told me his mother didn't have a camera. (P-2).*
>
> *Existing inequalities were undoubtedly reinforced. The refugee, for example, that I have in my class is already a vulnerable group in itself. They are the people who live over here in a house on the school site. This child has a big problem with language; we could not even communicate on the phone. When we were face-to-face, it was easier. With the signs he was showing you. Now, with the phone? The other kid has no computer or internet. How could he do anything? Of course, it reinforced the already existing inequalities (P-5).*
>
> *Students who previously had difficulties because of language or the educational level of their families... At the moment, they have absolutely no access to education. They cannot reach the teacher and communicate in any way, like the Roma or children whose parents are illiterate or do not speak Greek (P-6).*
>
> *Not all parents have tablets and computers, and there is no internet. There were many difficulties (P-8).*
>
> *There are inequalities. Some of the foreign students we have in the school don't have the means. Yes, we are talking about disparities (P-9).*
>
> *Since some children do not have a computer at home, they do not have the opportunity to get in touch with the whole educational process, even if it is at a distance. The children with the advantage of having a computer have the help of their parents, and indeed, the inequality among the students grows (P-10).*
>
> *It reinforced the existing social inequalities because those students who were thrown off continued to be the most thrown off. The ones who were previously excellent students, the ones who were taken care of at home, were also the ones whose parents provided them with infinite help in familiarizing them with the platform and the appropriate technological tools. They had computers, tablets, and their room (P-11).*
>
> *Not all students have the means (P-13).*
>
> *They contribute significantly to the reproduction of social inequalities. For example, a child with neither a computer nor anything at home is excluded. He has no contact with anyone. Others needed headphones, microphones, or an excellent mobile phone. They were asking parents how to get in. Many kids must get in (P-14).*
>
> *Online teaching has created new forms of inequalities. While all children used to come to school, now some can attend, and some cannot. Some children do not have access to online teaching, so inequalities are created (P-15).*

Teachers' suggestions for improving online teaching

To enhance the effectiveness of online teaching, the participating teachers proposed several measures. A key recommendation was the 'training of teachers', focusing on both pedagogical methods for online instruction and technical aspects of digital platforms. Additionally, teachers emphasized the need to 'train students' in navigating online teaching to help them develop the necessary digital literacy and learning culture.

> *Indeed, there should be training for teachers first and procedures for children. Not training, procedures in the school. Some communication with other schools, such as teleconferencing with students in other schools, could help them understand the culture of modern online teaching. However, training is needed for teachers because all of this was done very sloppily because of the extraordinary circumstances (P-1).*
>
> *For all this to happen, the children would have had to already have computer skills. I think that one hour of computer classes is not enough for the kids to gain skills (P-4).*
>
> *There should also be a training for all teachers. B2, for example, cannot have teachers participating by lottery due to a limited number of participants. There should be an opportunity for all teachers to be trained. There should be training beyond technical issues. There should be training on teaching, such as online teaching, if needed. To know how to behave! The IT lesson should have a module on how children can work on some platforms (P-8).*
>
> *It would work much better if students were already trained in such programmes in school in their IT lessons or if we were working on such platforms from September. Now, suddenly, telling students to go in and write... For some students, it was too difficult (P-10).*
>
> *Teachers should be provided with training (P-13).*
>
> *Teachers should have been trained in new technologies so that they avoid facing the problems that I faced, for example, due to unfamiliarity (P-15).*

In addition to training, several teachers proposed upgrading school infrastructure to support online teaching more effectively. This includes improving online teaching platforms, enhancing digital infrastructure, and ensuring that all students have access to the necessary technological equipment, such as computers, tablets, and stable internet connections. These improvements are seen as essential to ensuring equitable participation in online teaching and preventing educational inequalities.

> *Schools must have other equipment. That is, we can have lessons in the classroom, but new technologies must be part of the teaching so that children are already familiar with this way of teaching. Because*

now we would do something the kids were not ready for. Just because you can play with a mouse does not mean you can follow all that. Schools, in general, need to have other infrastructure to support this way (P-5).

First and foremost, the teachers stress the importance of 'guaranteeing access' to all students by providing them with laptops or tablets where none existed. They advocate for free Internet access and good lines to ensure effective communication, thereby promoting inclusivity in online education (P-6).

Equipment should have been given to all students earlier (P-11).

The Ministry's platforms need to be significantly upgraded. The platform that my school has chosen still doesn't work. I also think that the state should give students some financial tablet as soon as they come to school so that there are no financial disparities (P-14).

Discussion

The COVID-19 pandemic, a global crisis (Chu et al., 2020), has led to profound changes in the education sector, forcing a rapid transition to online teaching (Masali & Kougiourouki, 2022; Thanos et al., 2023). This transition from the traditional to the digital classroom has been an unprecedented challenge for all members of the school community (Thanos et al., 2023), sparking significant concern (Garbe et al., 2020; Hammerstein et al., 2021; Kim et al., 2021). However, it's important to note the remarkable resilience and adaptability demonstrated by teachers and students as they navigated this uncharted territory, often without adequate preparation (Thanos et al., 2023).

When implementing online teaching, flexibility and interaction characterize all the people involved, all the processes and all the means (Lionarakis, 2001b). The interaction between teachers and students, especially in times of crisis and emergency, is significant as it plays a crucial role in improving teaching quality and acquiring new knowledge (Sason & Kellerman, 2021; Zhang, 2023; Zhang, 2022). The teachers in the study reported interaction with their students during online teaching, mainly through the digital platforms they used. This view of the teachers is confirmed by the findings of related research (Kritikos et al., 2021; Nikolaou, 2023; Sfantou, 2020). However, regarding the interaction between students during online teaching, the teachers in the study reported that it was much lower than in the classroom, which aligns with the findings of a recent study (Malisiova, 2021).

The implementation of online teaching during this period had some advantages and disadvantages (Decarli et al., 2022; Zhang, 2023). According to the participants' opinions, the main advantages of online teaching during COVID-19 are that it served as a safe means to ensure continuity in the teaching process, allowing the maintenance of communication between students and teachers. At the same time, it contributed significantly to the development of new IT skills for teachers and students and to the enhancement of students' autonomy. These findings are in line with the findings of related studies (Cardullo et al., 2021; Decarli et al., 2022; Malisiova, 2021; Mouzakis et al., 2021; Nikolaou, 2023; Soutopoulos & Georgitsis, 2021; Zhang, 2023). Another advantage of online teaching, according to the participants, is that it contributes to the psychological support of the students and the strengthening of the feeling of belonging to a group. One teacher says: 'Students feel that there is this feeling of belonging to a group. It helps them psychologically' (P-15). Indeed, providing psychological support to students is particularly important, as they are psychologically affected by extraordinary circumstances, such as the pandemic period (Marques de Miranda et al., 2020; Mouzakis et al., 2021).

On the other hand, significant problems emerged during the implementation of online teaching, which influenced its effectiveness. According to recent research studies, one of the disadvantages was related to the impersonal nature of online teaching, as there was no direct human contact between teachers and students. In addition, technical issues with online teaching platforms emerged, including malfunctions and access problems, making it challenging to manage the teaching process smoothly (Soutopoulos & Georgitsis, 2021). At the same time, the informative instructions from the Ministry of Education were not timely and adequate, adding additional difficulties to implementing and realizing online teaching (Thanos et al., 2023). The participants also pointed out these drawbacks.

The participants also reported facing challenges during online teaching due to their general lack of training in new technologies and online teaching. Other related studies also highlight this view of teachers (Cardullo et al., 2021; Mouzakis et al., 2021; Thanos et al., 2023). Furthermore, teachers reported that students' insufficient familiarity with new technologies and using online teaching platforms was an additional barrier, especially for the weaker students and students with special educational needs, who faced increased difficulties approaching online teaching. One teacher says: 'A portion of students, for example, with learning difficulties or special educational needs, you cannot reach them well at a distance. Children with autism, who do not have much verbal skills, see you on the camera; you ask them questions, and they do not answer. Whereas in person it would be easier' (P-7). These findings are in line with the findings of recent related research (Cardullo et al., 2021; Decarli et al., 2022; Di Pietro et al., 2020; Malisiova, 2021; Mouzakis et al., 2021; Soutopoulos & Georgitsis, 2021).

Another disadvantage that emerged during online teaching, according to the responses of the participants, is the reinforcement of existing social inequalities and the emergence of new forms of inequalities. In particular, teachers reported that some students' need for more logistical infrastructure affected their learning, unlike other classmates who had the necessary resources. In addition, the situation of students from vulnerable social groups, non-speaking Greeks, or families with a low education level presenting difficulties in accessing and participating in online teaching was highlighted. Indeed, as reported in several studies, online teaching implemented during the COVID-19 period contributed to the increase of social inequalities, having a particular impact on students from economically, socially and culturally vulnerable groups (Cardullo et al., 2021; Carretero Gomez et al., 2021; Mouzakis et al., 2021; Nikolaou, 2023; Thanos et al., 2023).

Addressing and reducing social inequalities should be a top priority for all countries, especially in times of crisis such as the COVID-19 pandemic. At the national level, equity-based interventions are crucial to mitigate socioeconomic inequalities (Chu et al., 2020) and ensure that all students have equal learning opportunities (Nikolaou, 2023). This suggestion is also echoed by the participants. To improve online teaching, they propose that all students should be provided with the necessary equipment, such as computers and tablets, to ensure everyone can participate in online teaching and prevent inequalities. Additionally, at the state level, teachers recommend upgrading schools' equipment, infrastructure, and online teaching platforms to further bridge the digital divide.

Furthermore, the participants suggest training students on how online teaching works in order to acquire the necessary culture and cultivate the corresponding skills since, as mentioned above, students' familiarity with new technologies and the use of online teaching platforms was insufficient (Cardullo et al., 2021; Decarli et al., 2022; Mouzakis et al., 2021). To improve online teaching, the research participants also suggest training teachers on online teaching, both on teaching and technical issues, a suggestion that is also highlighted in other related studies (Nikolaou, 2023; Soutopoulos & Georgitsis, 2021). Indeed, in order to improve distance teaching, training of all teachers is necessary (Anastasiadis, 2020).

Conclusions-Limitations of the Research

The COVID-19 pandemic brought major changes in various sectors worldwide, highlighting significant social, economic, medical and educational challenges (Nicolau et al., 2020). In education, the changes were rapid, with online teaching emerging as a central factor for continuing the teaching process (Masali & Kougiourouki, 2022; Thanos et al., 2023). The adoption of online teaching, both nationally and internationally (Doz & Doz, 2023; Evangelou, 2022), has been an unprecedented challenge (Kim & Asbury, 2020), forcing teachers to quickly adapt to a new reality where teaching is moving to the digital space (Thanos et al., 2023).

This study contributes to understanding the challenges and opportunities that emerged from implementing online teaching in Greece during the COVID-19 pandemic, providing valuable insights for improving the quality and effectiveness of online teaching. According to the opinions of the teachers who participated in this research, it is concluded that:

- Interaction between students during online teaching was much less than in the classroom, which is consistent with the findings of a recent study (Malisiova, 2021).
- There was interaction between teachers and students during online teaching, mainly through their digital platforms, as found in another bulk of research (Kritikos et al., 2021; Nikolaou, 2023; Sfantou, 2020).
- The advantages of online teaching are that it acts as a secure means to ensure the continuity of the teaching process, allowing the maintenance of communication between students. At the same time, it contributed to the students' psychological support and reinforced their sense of belonging to a group. It also contributed significantly both to the development of new IT skills for teachers and pupils and to the enhancement of pupils' autonomy. These advantages are also highlighted in the literature (Cardullo et al., 2021; Decarli et al., 2022; Malisiova, 2021; Mouzakis et al., 2021; Nikolaou, 2023; Soutopoulos & Georgitsis, 2021; Zhang, 2023).
- The disadvantages of online teaching include the impersonal nature and lack of direct human contact between teachers and students, technical issues and malfunctions of online teaching platforms, insufficient training of teachers in new technologies and online teaching, insufficient and untimely information instructions from the Ministry of Education. Furthermore, the insufficient familiarity of students with new technologies and online teaching platforms was an additional obstacle, especially for the weaker students and students with special educational needs, who faced increased difficulties in approaching online teaching. Online teaching also reinforced existing social inequalities and created new forms of inequalities. These findings are in line with the findings of recent related research (Cardullo et al., 2021; Carretero Gomez et al., 2021; Decarli et al., 2022; Di Pietro et al., 2020; Malisiova, 2021; Mouzakis et al., 2021; Thanos et al., 2023; Soutopoulos & Georgitsis, 2021).
- To improve online teaching, they suggest the training of teachers on teaching and technical issues, the training of students

to acquire the necessary culture and cultivate the corresponding skills, the upgrading of equipment and infrastructure of school units, the upgrading of online teaching platforms and the coverage of all students with the necessary technological equipment and internet access, to ensure the participation of all and to avoid inequalities. Other studies also highlight these suggestions (Chu et al., 2020; Nikolaou, 2023; Soutopoulos & Georgitsis, 2021).

In this study, certain limitations should be mentioned and taken into account. Firstly, the research sample is not representative and the results and conclusions of the research cannot be generalized. Also, the use of a single research instrument does not allow for the triangulation of the findings, which limits the validity of the testing of the resulting data. Another limitation is the need for similar studies in Greece and internationally focusing on teachers' views on implementing online teaching during the COVID-19 pandemic. This lack limits the discussion of the results and their comparison with those of other studies.

Disclosure statement

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Investigating Students' Leisure-Time Reading Preferences in Upper Primary Classrooms in Fiji

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Abstract

This quantitative study investigated upper primary school students' leisure time reading preferences in Fiji. A structured questionnaire was administered to 92 students in Years 7 and 8 of a select school in western Fiji. The findings revealed that the majority of students engaged in leisure reading, with storybooks being the most preferred reading material, followed by newspapers, magazines, online materials and religious texts. Adventure stories emerged as the most popular subgenre, and horror, comedy, romance, and suspense were also preferred by students. The study identified specific titles and authors that captured the students' interest, with J.K. Rowling's Harry Potter series being the most popular. These findings challenge the notion that students do not read during their leisure time and highlight the importance of promoting and supporting reading habits among young learners. The study has significant implications for teachers, parents, and policymakers in promoting literacy and cultivating a love for reading. Teachers can accommodate students' diverse interests by incorporating a variety of reading materials and genres into educational settings. Parents can encourage reading at home by providing access to books and modelling positive reading habits. Policymakers can support literacy initiatives by investing in well-stocked libraries and promoting community-based reading programmes. By understanding and nurturing students' reading preferences, stakeholders can create an environment that encourages lifelong learning and enhances overall academic achievement.

Keywords:

Reading, Literacy, Reading for Pleasure, Leisure Reading, Comprehension

Introduction

Reading in leisure time plays a fundamental role in students' academic and personal development, particularly in upper primary classrooms where reading habits are still being shaped. Developing a strong reading culture during this period can improve literacy skills, foster creativity, and contribute to lifelong learning. However, understanding students' reading preferences during leisure time is essential for teachers, parents, and policymakers to design effective literacy programmes and interventions that align with student interests.

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Sustainable Development Goal 4 aims to ensure inclusive and quality education for all, focusing on promoting lifelong learning and acquiring basic literacy skills, including reading. Reading is defined as the process of deriving meaning from text (Cline et al., 2006). Developing this skill is crucial for students to achieve success in life, as children who read frequently and widely tend to outperform their peers who do not. Reading enables students to better understand their beliefs, values, and aspirations. In addition, it allows them to understand the lives of others, fostering empathy and a sense of compassion. According to Putra et al. (2012), reading is an essential skill for all students, regardless of their level of education. It is one of the four language skills that students must master to comprehend texts fully. While some students read for academic purposes, others read for pleasure. Several studies have been conducted to identify students' literacy interests in their classrooms (Anderson, Wilson, et al., 1988; Greaney, 1980; Lagi, 2019; Shameem, 2002). These studies consistently show that reading books in one's leisure time is the best predictor of measures of reading achievement. However, most students rarely participate in this activity. Research has also demonstrated that reading helps students succeed, but there is little research on students' reading habits during leisure time, particularly in Fiji. This study addressed this research gap by investigating what students read in their leisure time and their preferences for books and authors. By identifying these preferences, teachers can better support students in developing positive reading habits that extend beyond the classroom and into their daily lives.

The findings of this research will provide valuable insight into how reading preferences evolve in upper primary years and inform strategies to foster a reading culture that aligns with students' interests and needs.

Literature Review

For a considerable period of time, children's literature has served as a supplement to the curriculum in many classrooms, a tradition that continues in some areas today. However, over the past three decades, teachers have increasingly acknowledged the vital role that children's literature plays in fostering literacy (Gamble, 2019; Leland et al., 2022). This shift in pedagogy during the 1980s and 1990s, from the use of highly structured literacy materials to the incorporation of children's literature, has elevated the importance of children's literature in teaching reading (Florence, 2017; Gabrielsen et al., 2019; Leland et al., 2022). The transition from literacy materials to children's literature demonstrates the significance of leisure reading as a crucial aspect of literacy. Leisure reading not only provides enjoyment but also promotes learning (Garces-Bacsal et al., 2018). Through participation in leisure reading, students develop skills beyond the basic literacy components. They begin to recognise textual patterns and connections between various literary texts, enhancing their comprehension and discourse (Deane, 2020).

Reading is a crucial skill that plays a significant role in the cognitive development of young minds. According to Castles et al. (2018), effective reading habits help children gain practical, meaningful knowledge. To understand the meaning of written text, readers must determine and derive meaning from printed words (Foorman et al., 2016; Tulomana et al., 2023). The process involves converting the written symbols into linguistic sound symbols and using language knowledge to reassemble the writer's message. Zainal and Husin (2011) emphasise that reading is a cognitive skill that requires the reader to apply various abilities such as inferring, questioning, predicting, and making conclusions to extract information from the text. Reading also allows one to reflect on previously held beliefs and introduce new ideas. Ainscow and Messiou (2017) highlight that reading can stimulate the reader's thinking and provide context for previously held beliefs.

Reading plays a crucial role in the practical aspects of our lives, as evidenced by numerous biographies and autobiographies that emphasise its significance. For instance, in the autobiography Gifted Hands: The Ben Carson Story (Carson & Murphey, 1992), Ben Carson highlights the impact of reading on his personal development. He recalls developing a passion for reading about animals and nature, which improved his skills in identifying rocks and improved his performance in school. Visiting the library regularly expanded his interest in other genres and categories, resulting in better vocabulary and comprehension. Reading also helped him solve mathematical problems by enhancing his critical thinking skills. The positive effects of leisure reading, as demonstrated by Ben Carson's experiences, are undeniable and far-reaching.

According to numerous studies, many students do not have a habit of reading frequently. For example, Zafar (2018) found that very few preschool and primary-grade students opt to read books during their free time at school. Greaney (1980) discovered that fifth-grade students spent only 5.4% of their out-of-school free time reading, and 23% read nothing. Furthermore, a study by Delgado et al. (2018) revealed that students spend little free time reading. In addition, research conducted in various parts of the world, including Singapore and the United States, has shown a steady decline in reading habits as children age (Ferguson, 2020; Gander, 2013).

Scholars from diverse fields have investigated how much time students spend reading and its impact on cognitive functions. Foorman et al. (2016) found a

strong relationship between reading and academic achievement. They asserted that a student who is a proficient reader is more likely to succeed academically and pass exams than a student who is a poor reader. Furthermore, they discovered a strong correlation between reading ability and vocabulary knowledge. As a result, students who read widely tend to have a large vocabulary. Similar findings were reported by Kumar (2017), who also highlighted the importance of reading in academic achievement. Therefore, determining whether students read and what they read is equally important.

According to Cunningham (2019), reading storybooks stimulates imagination in students and unlocks a treasure trove of experiences that transcend time and distance, connecting people in meaningful ways. By reading, individuals gain a wealth of experience, enabling them to broaden their perspectives, intensify and expand their interests, and deepen their understanding of themselves, other human beings, and the world. With the emergence of new genres such as cli-fi or climate fiction, traditional literary genres are being supplemented, and reading interests are evolving.

Several researchers and teachers agree that exposing students to diverse and high-quality books helps them develop an appreciation for literature (Baba & Affendi, 2020; Fountas & Pinnell, 1996). Rapanta et al. (2020) emphasised the importance of reading in preparing young students for entry into the realm of literacy. Reading aloud to young students is widely regarded as the most effective method for building the knowledge necessary for eventual reading success (Anderson, Hiebert, et al., 1988; Senawati et al., 2021).

Evans et al. (2014) posited that books in a home environment positively impact a child's educational attainment. Evans additionally emphasised that the availability of books at home is more critical than the father's level of education and more essential than the child's socioeconomic background. Baker et al. (2020) and Chandra and Chand (2024) argued that teachers who read aloud to their students foster strong language and reading comprehension skills in their students. The advantage of having books at home and reading to children from an early age is that it exposes them to literacy and promotes a lifelong love of reading. When reading becomes a habit, literacy development is likely to follow.

According to Ganapathy and Seetharam (2016), increasing the availability of books and employing them to stimulate language and play activities can improve literacy levels. Scholars widely accept that reading interest is closely tied to one's concepts, opinions, and attitudes toward learning (Florence, 2017; Nespor, 1987). The National Reading Panel (US) (2000) posits that reading interest can contribute to developing a positive literacy attitude. Reading interest can serve as a driving force for people to acquire and develop knowledge based on their unique requirements and needs. This notion is supported by Vig and Sharma (2014), who argue that reading interests can influence lifelong learning and continuing education.

Language instructors frequently prioritise independent reading, exposing students to authentic literature from their initial interactions with print and incorporating sustained silent reading time in their classrooms. Studies indicate that students who read books at school are more likely to continue this activity outside of the classroom environment (May & Elder, 2018). Despite this, research suggests that some teachers lack the necessary knowledge of children's literature, which can hinder their ability to introduce students to the wide range of books available and may result in ignorance of the influence their teaching methods have on students' attitudes toward reading (Mohammed, 2018).

The notion that students who engage in considerable amounts of voluntary reading have a positive attitude toward reading is supported by both qualitative and quantitative evidence. Research conducted by Ahmadi (2017), Busse (2017), Greaney (1980), Mohammed (2018), Stutz et al. (2016) and Tsang and Fung (2023) all point to this conclusion. It is also well-established that students' reading achievement is closely related to their academic success and the amount of independent reading they do (Delgado et al., 2018; Greaney, 1980; Majid, 2018). These findings suggest that the more one reads, the more proficient they become at reading.

Independent reading, often referred to as leisure reading (Greaney, 1980), free time reading (Searls & Ward, 1985), recreational reading (Manzo & Manzo, 1995) and reading outside of school (Mohammed, 2018) has consistently been associated with increased vocabulary, reading comprehension, verbal fluency, and general knowledge (Delgado et al., 2018; Greaney, 1980; Guthrie & Greaney, 1991; Majid, 2018). Students who engage in independent reading tend to develop into stronger readers, perform better on achievement tests, and have a greater grasp of the subject than those who do not read independently (Cunningham & Stanovich, 1991; Majid, 2018; Stanovich & Cunningham, 1993).

According to Shameem (2002), English proficiency is emphasised at all levels of primary education in Fiji. Lagi (2019) conducted a small-scale study in a primary school in Ovalau to identify students' primary literacy difficulties and the methods employed by teachers to overcome them. Her findings revealed that phonology (speech sounds) and orthography (spelling patterns) are students' two most significant literacy problems.

Marx (2018) highlighted that regular monitoring of phonics and reading assessments leads to measurable outcomes. In addition, targeted phonics courses benefit students struggling with reading. Kumar (2017) underscored the significant relationship between pleasure reading and academic achievement. Students who read a substantial amount of fiction for pleasure tend to perform well on English tests (Kumar, 2017).

The ongoing efforts of education stakeholders to improve literacy have achieved considerable progress. However, the issue of illiteracy, particularly in reading, remains a significant concern. As Lacanivalu (2017) noted, there are legitimate concerns raised by education stakeholders regarding the impact of modern communication technologies, such as texting and Facebook, on children's reading habits. This concern is supported by numerous international studies, including Bal (2018) and Sari et al. (2020), which have documented the negative effects of the digital age on pleasure reading and the decline of the English language standard.

Since 2009, the Programme for International Student Assessment (PISA) has revealed that students who have a fondness for reading consistently outperform their peers in literacy assessments (OECD, 2021). Similarly, the International Association for the Evaluation of Educational Achievement (2007) reports that students with a positive attitude toward reading perform well in the Progress in International Reading Literacy study. However, reading abilities can be hindered if students struggle to access storybooks or lack the time to read them. Unfortunately, the International Literacy Association (2020) notes that the issue of access to books and the opportunity to read remains a significant concern in several countries and states.

Children denied access to books during their formative years often struggle to cultivate healthy reading habits (Deavers et al., 2000). Palani (2012) states that fostering healthy reading habits is essential for building a literate society. Reading not only shapes one's personality but also promotes critical thinking. Palani (2012) posits that effective learning is linked to effective reading habits, where readers quickly identify symbols and their associated meanings, ultimately leading to comprehension. When students understand the texts, they ultimately learn (Bhan & Gupta, 2010; Majid, 2018; Ogbodo, 2010; Singh, 2011).

Background and context of the study

Fiji comprises approximately 330 islands in the Pacific Ocean, located between the equator and the south pole. With roughly one-third of its islands inhabited, the total land area spans roughly 18,333 square kilometres. The archipelago has two significant islands: Viti Levu and Vanua Levu. Of these, Viti Levu is the largest and the location of Fiji's capital, Suva, where most Fijians reside.

Due to its location, Fiji faces various challenges in educating its population. The Ministry of Education has continued difficulties supplying curriculum materials, conducting professional development workshops, and ensuring internet and communication services in remote schools. The nation's geographical features and its remote location in the Pacific make delivering education to its children and people a significant challenge (Tikoisuva, 2000). Like other Pacific Island nations, Fiji adopts a centralised curriculum development approach (Chand, 2015; Koya, 2015).

Fiji has a rich oral tradition in which the stories of its history, folklore, myths, and legends are transmitted orally through recitation and storytelling. The advent of print culture in Fiji can be traced back to the arrival of Christian missionaries in 1835. With the establishment of The Fiji Times, a daily newspaper, in 1869, information became more accessible to the public. English written works gained prominence in areas such as news reporting, advertising, and education. According to Lotherington (1998), the Fijian population has yet to develop a significant literate tradition beyond ritual reading patterns, including religious texts, newspapers, and school materials. This may explain why the culture of reading books at home or school has not taken root strongly.

Literature in English for adults has achieved a notable position with the emergence of writers, authors, poets, and playwrights who have produced a distinctive blend of Fijian literature. The publication of literature in Fiji has a history of approximately half a century. Some prominent Fijian writers include Pio Manoa, Raymond Pillai, Satendra Nandan, Subramani, Vilisoni Hereniko, Larry Thomas, Joseph Veramu, and Sudesh Mishra. Emerging writers also work in both English and their vernacular languages. Although these writers have written about various topics, such as Fijian, Indian, colonial projects, postcolonial, independence, coups, political landscape, and modern and postmodern literature, there are no significant contributions to children's literature.

Since independence, the 2000 Education Commission highlighted that a major concern of successive governments has been ensuring equal access to educational facilities for all children (Bacchus, 2000). Bacchus said that though formal, there is concern about education and its quality. One of the significant recommendations for improvements in the primary schools made by the 1969 Education Commission was to increase the supply of books and reading materials amongst the students in schools.

Research Questions

The following research questions guided the study:

1. Do students read storybooks for pleasure in their leisure time?
2. What are the preferred genres among primary school students in Fiji?

Methodology

This quantitative research aimed to determine whether upper primary school students in Fiji engage in pleasure reading. An exploratory case study design was deemed appropriate for this study as it sought to provide preliminary information regarding children's leisure time reading, which can be utilised to draw hypotheses for further research with specific intentions, such as investigating the correlation between student leisure reading and their spoken English or their academic achievements (Mills et al., 2009).

Students in years 7 and 8 of a select school in western Fiji were purposefully chosen for this study. This age group was chosen because they possess the ability to complete the questionnaire with minimal assistance. Ethical guidelines were followed, including obtaining approval from the Ministry of Education and the school being studied. Participation in this study was voluntary, and a parental consent form was provided to all students in years 7 and 8 for their child's participation in the research.

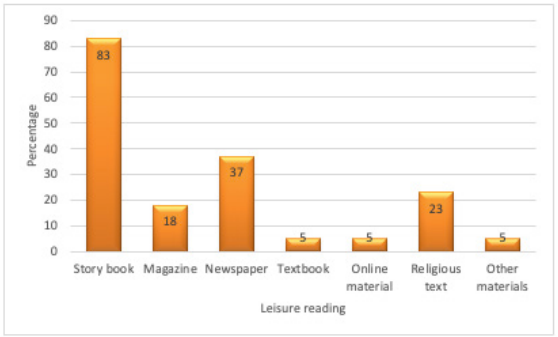
The case study school had 120 students in grades 7 and 8. The parental consent form was sent to all parents, and 77% (n=92) responded positively. A structured questionnaire was used as the primary instrument for data collection. The questionnaire used existing literature on children's reading preferences and was adapted to the unique Fijian setting to ensure cultural relevance. It included sections on reading frequency, preferred genres, and motivations for reading. The questionnaire was pilot-tested with a select group of students from a comparable population to assess the clarity, comprehension, and appropriateness of the questions. Minor adjustments were made to enhance the language and structure of the questions based on the feedback received. These 92 students were asked to complete the final version of the questionnaire, which consisted of closed-ended questions with Likert scale options. The data collected were analysed using simple descriptive statistics, including frequency counts and percentages, which are represented in the form of bar graphs.

To establish the validity of the research instrument, expert opinions were obtained from experienced teachers and literacy specialists to assess its content validity. The researcher ensured reliability by being thorough, careful, and honest in conducting the research.

Results of the study

The participants were presented with seven options to choose from in relation to their leisure-time reading habits: storybooks, magazines, newspapers, textbooks, Internet materials, and religious texts, among others. Most of the respondents indicated that they preferred to read storybooks, which were found to be the most popular choice. Newspapers were the second most popular option, followed by the other choices that received less attention. The preference for leisure-time reading is illustrated in Figure 1.

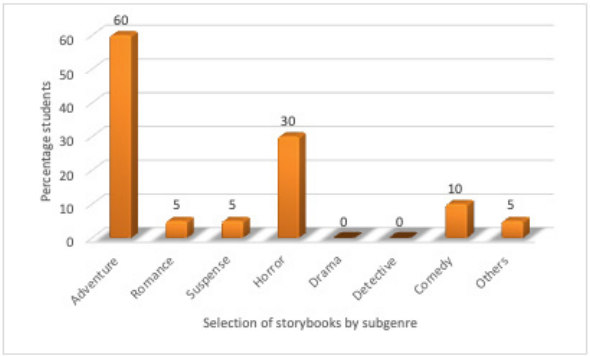
Figure 1.
What do students read in their leisure time?



When asked about the number of books they had read, 55% of the participants reported reading more than eight storybooks; 10% read between thirteen and fifteen books, 10% read between sixteen and eighteen books, and 15% read more than twenty-one books in a single year. The remaining individuals had read fewer than eight books and one participant had read only two storybooks.

When selecting books from subgenres, most participants chose adventure storybooks (60%). However, a closer examination of subgenre preferences reveals that horror stories also attract a considerable readership, suggesting a nuanced taste among students. On the contrary, only a small percentage of participants preferred suspense, romance, drama, detective fiction, or comedy, among other subgenres. The distribution of storybooks across different subgenres is illustrated in Figure 2.

Figure 2.
Selection of storybooks



When asked about their favourite titles, the students exhibited a high degree of discernment in their selections. They mentioned a variety of titles, including Beast Quest, Teacher's Pet, Rain of the Moon, Goosebumps, Harry Potter, Strongman, Cinderella, My Book of Bible Stories, Swiss Family Robinson, Dork Diaries, Lily Alone, Treasure Island, and Malory Towers. A critical analysis of these choices reveals a preference for both classical and contemporary literature, reflecting diverse literary influences. Harry Potter emerged as the most popular title among the options listed. The authors associated with these works included Adam Blade, Chris Demarest, Tom McCaughhren, RL Stine, Jules Verne, Stepanie Greene, Walt Disney, Johann Wyss, Rachael Renee Russell, J. K. Rowling, Jacqueline Wilson, Johanna Spyri, Briana and Enid Blyton. Rowling was the preferred author among the participants and her works were the most frequently cited. The most popular subgenre among students was adventure, followed by horror, comedy, romance, and suspense. These findings emphasise the need to explore how popular authors influence students' reading choices and preferences.

Discussion of findings

The findings of this study reveal significant insights into the leisure reading preferences of primary school students, offering a contrast to previous studies while highlighting the diverse genres and materials that capture their interest. A deeper critical evaluation suggests that students' preferences may be influenced by factors such as peer recommendations, media exposure, and accessibility of reading materials.

Previous research conducted by Delgado et al. (2018), Greaney (1980), and Zafar (2018) suggested that reading books in one's leisure time was the strongest predictor of reading achievement. These studies also found that most students did not read significant amounts of books on a daily basis. On the contrary, the present study found that primary school students prefer to read stories during their free time. These students not only read storybooks, but also enjoy reading newspapers, magazines, online books and materials, and religious texts. When it comes to subgenres, adventure stories are the most popular, followed by suspense, romance, horror, and comedy. One possible explanation for these findings may be that storybooks provide an escape from reality. Through immersion in different worlds, time periods, or fantastical settings, readers can temporarily relieve themselves from the pressures of everyday life and stimulate their imagination. Another possible explanation for this could be that many stories contain characters and situations that readers can relate to, allowing them to empathise with the experiences and emotions of the characters. This emotional connection can be deeply satisfying and enhance the reader's enjoyment of the book. Further analysis is required to determine whether the appeal of adventure stories stems from their narrative structure or thematic elements.

Castles et al. (2018) discovered that cultivating effective reading habits in children can lead to the acquisition of practical knowledge. For example, one such practical knowledge is the ability to select an appropriate title to read. Students often identify popular titles that suit their interests or recommendations from peers and teachers. In this study, numerous titles preferred by students were identified. Among these, Harry Potter emerged as the most popular title, with J.K. Rowling being the most preferred author. The Harry Potter series has garnered a wide readership among children because of its captivating and imaginative narrative. It would be valuable to investigate whether the preference for Rowling's work is due to thematic depth or its widespread cultural impact.

This research indicates that a substantial number of students engage in leisurely reading. Although some students have an insatiable appetite for books (15%), others selectively choose what they read (55%). The salient assumption is that all students, irrespective of their reading habits, occasionally peruse storybooks, contrary to a commonly held belief among parents and teachers. Storybooks are the most preferred reading material. Adventure stories remain the most beloved subgenre, but students also show interest in suspense, romance, drama, detective fiction, and comedy. This finding calls for further exploration of how educational policies can support and promote leisure reading.

Conclusion and implications of the study

Research suggests that most primary school students participate in leisure reading, with storybooks being their preferred choice of reading material. Contrary to popular belief, children do not limit their reading to storybooks; they also read newspapers, magazines, online materials, and religious texts during their free time. Adventure stories emerged as the most popular subgenre, followed by horror, comedy, romance, and suspense. The study also underscores the importance of effective reading habits in acquiring practical knowledge, as evidenced by students' preferences for specific titles and authors, with J. K. Rowling's Harry Potter series being the most popular. These findings challenge the notion that students do not read during leisure time and emphasise the importance of promoting and supporting reading habits among young learners.

This study presents several implications for teachers, parents, and policymakers in promoting literacy and cultivating a love for reading among primary school students. To encourage primary school students to read more, teachers and parents must recognise

the variety of materials children engage with during their leisure time, including newspapers, magazines, online content, and religious texts. Teachers can accommodate students' varied interests and preferences by incorporating these diverse materials into educational settings. Understanding students' preferred subgenres, such as adventure, horror, comedy, romance, and suspense, can help teachers and parents select appropriate reading materials. By offering a wide range of books across different genres, they can cater to individual tastes and encourage students to explore new genres. Incorporating popular titles and authors, such as J. K. Rowling's Harry Potter series, can also capture students' interest and enthusiasm for reading. Research shows that effective reading habits are essential to acquiring practical knowledge, and teachers and parents can emphasise the importance of cultivating strong reading habits, such as regular reading routines and active comprehension strategies, to help students derive meaningful insights from their reading materials. Policymakers can also play a crucial role in ensuring that primary schools have sufficient resources and access to diverse reading materials by investing in well-stocked libraries, providing funding for classroom libraries, and promoting initiatives that encourage reading at home and in the community.

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The Effect of Academic Resilience and Self-Regulated Learning on Students' Social Studies Learning Outcomes

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Abstract

Academic resilience and self-regulated learning significantly enhance student performance in social studies. However, these two critical factors are often underutilized in educational strategies. Effective social studies outcomes depend not only on academic prowess but also on psychological aspects such as academic resilience and self-regulated learning, which are crucial for student success. The purpose of this study was to investigate the effect of academic resilience and self-regulated learning on students' social science learning outcomes. This research method was a quantitative approach with elementary school students in Ambon, Indonesia with a total sample of 265. Data collection used a questionnaire instrument regarding academic resilience and self-regulated learning on students' social studies learning outcomes. Analysis of the research data used a structural equation model (SEM) with the help of the SmartPLS 3.0 application program. The findings of this study reveal that academic resilience and self-regulated learning significantly and positively impact students' social studies learning outcomes. Developing these skills among students can be an effective strategy to enhance their performance in social studies. Furthermore, the study emphasizes the importance of non-academic factors, such as resilience and self-regulation, in comprehending and improving educational outcomes in social studies. These insights suggest educators should integrate strategies that foster these psychological competencies to support student's academic success.

Keywords:

Academic Resilience; Learning Outcomes; Self-Regulated Learning; Social Studies

Introduction

The currently implemented education curriculum in Indonesia encourages teachers to raise the latest issues Education plays a crucial role in opening the door to developing students' potential and success in various aspects of life (Aiello et al., 2021; Mariati et al., 2021). Students through education are provided opportunities to hone skills, broaden knowledge, and develop the potential that exists within them. Students with a solid educational foundation can certainly achieve success in the future, both in their careers and in their personal lives (Kümmel et al., 2020;

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Triasningsih, 2020). Education gives them the tools to face challenges, create opportunities, and contribute positively to society.

Education is an important aspect of developing students' potential and success in life (Wulandari et al., 2023). Social science in the context of education is one of the subjects that provide an understanding of society, politics, economics, and culture (Amrina et al., 2020; Edinyang et al., 2020). Students in social studies learning not only learn facts and concepts but are also involved in a deeper understanding of how humans interact, how political decisions are made, how the economy operates, and how culture influences everyday life (Katilmis et al., 2011; McCorkle, 2020). Good social studies learning outcomes do not only depend on students' academic abilities but also on psychological factors that can affect their learning process.

Quality social studies learning outcomes do not only depend on students' academic abilities alone but are also influenced by psychological factors that influence their learning process (Sejati et al., 2019; Wahidmurni et al., 2021). Social studies learning outcomes also include students' ability to apply their knowledge in analyzing social situations, identifying problems, and formulating solutions based on contextual understanding. Solichin's et al., research (Solichin et al., 2021) explains that students' social studies learning outcomes in elementary schools are still low because there are challenges that need to be overcome in increasing learning achievement in social studies subjects. This low learning result can be caused by various factors, including ineffective teaching methods, inadequate curricula, and a lack of attention to psychological factors that affect student learning processes. Although intellectual intelligence has an important role in obtaining good learning outcomes, of course, other factors such as academic resilience and self-regulated learning also have a significant influence (Hartikainen et al., 2019; Syaifuddin et al., 2021; Ummah et al., 2020).

Intellectual intelligence involves students' ability to understand concepts, absorb information, and apply knowledge in the social studies context. However, several psychological aspects can affect the extent to which this intellectual intelligence can be expressed and applied effectively (Graham et al., 2020; Sahronih et al., 2019). Academic resilience is the ability of students to overcome learning challenges and recover from failures or difficulties they may face (Hunsu et al., 2023). Academic resilience in social studies learning helps students stay motivated and focused on learning goals even though they face material complexity or difficulties in understanding socio-political aspects (Naqiyah, 2022; Salas-Pilco, 2020; Wills & Hofmeyr, 2019). The ability to face failure, learn from failure, and keep moving forward is an important factor in achieving good learning outcomes in social studies learning.

Good social studies learning outcomes can also be obtained through the important role of self-regulated learning. Self-regulated learning involves students' ability to regulate and control their learning process (Putri et al., 2020). Students who can set clear learning goals, plan effective learning strategies, monitor their learning progress, and carry out self-evaluations tend to achieve better learning outcomes in social studies learning (Sabrillah et al., 2021; S.G et al., 2023). This ability enables students to manage time, adopt effective learning strategies, and have strong intrinsic motivation in achieving a deep understanding of social issues.

Previous research (Galizty & Sutarni, 2021; She et al., 2023; Yoelianita & Toga, 2022) has explained that academic resilience and self-regulated learning in social studies learning can affect students' social studies learning outcomes. These two factors, both academic resilience and self-regulated learning, have an important role in increasing social studies learning outcomes. Students who have a high level of academic resilience tend to be better able to deal with learning difficulties, maintain motivation, and recover from failures or negative events in the learning process. Students through self-regulated learning can optimize their time and resources, adopt study techniques that suit their needs, and develop the analytical and reflective skills needed to understand social issues in social studies (Saufi et al., 2022; Sutarni et al., 2021). This research expands and deepens previous findings by simultaneously analyzing the interaction between academic resilience and self-regulated learning on students' social studies learning outcomes using the Structural Equation Modeling (SEM) method. This study offers a new perspective by including contextual factors in social studies learning, such as teaching methods and learning environment support. The results of this study are expected to contribute to developing more effective learning strategies based on students' psychological aspects.

This study aimed to comprehensively analyze the impact of academic resilience and self-regulated learning on students' social studies learning outcomes. Academic resilience and self-regulated learning are crucial in enhancing students' academic performance in social studies. Students with high academic resilience are more likely to apply self-regulated learning strategies effectively. In contrast, those who engage in self-regulated learning can further strengthen their academic resilience in overcoming challenges in social studies. Therefore, educators and mentors should provide targeted support and guidance to foster academic resilience

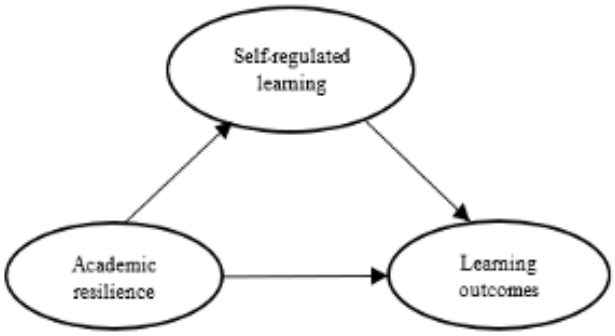
and self-regulated learning, ensuring an optimal learning environment for students.

Research Method

Research design

This study employs a quantitative method with a correlational design, aimed at analyzing variables that can predict outcomes using a Structural Equation Modeling (SEM) approach (Balnaves & Caputi, 2018; Z. Deng, 2023; T. Teo, 2014). The conceptual model of this research is titled "The Influence of Academic Resilience and Self-Regulated Learning on Students' Social Studies Learning Outcomes." In this model, academic resilience (AR) and self-regulated learning (SRL) are treated as exogenous variables, while social studies learning outcomes (LO) are considered endogenous. Academic resilience is posited to directly influence self-regulated learning, which in turn directly impacts social studies learning outcomes. Additionally, the model explores indirect relationships, such as the influence of academic resilience on social studies learning outcomes mediated through its positive impact on self-regulated learning. The research path model is illustrated in Figure 1 below.

Figure 1.
Research model framework



Population and Sampling

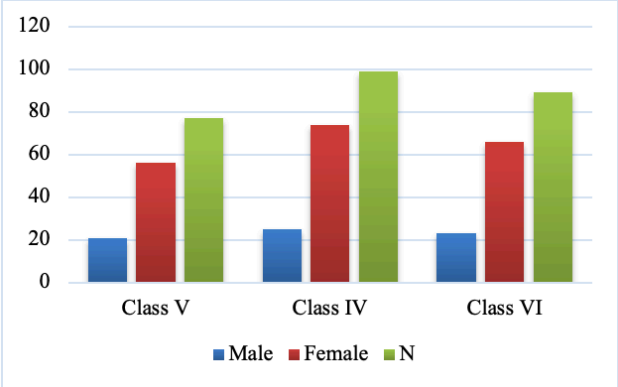
The study applied specific inclusion and exclusion criteria to ensure a representative sample of elementary school students in Ambon, Indonesia. Participants were required to be enrolled in one of the selected schools—State Elementary School 92 Ambon, State Elementary School 58 Ambon, Inpres Elementary School 58 Ambon, Inpres Elementary School 57 Ambon, or Pattimura University Laboratory Elementary School—and be in grades IV, V, or VI. Additionally, parental or guardian consent was mandatory for participation. Students who were not enrolled in these schools, did not belong to the specified grade levels, or lacked consent were excluded. These criteria ensured a focused, ethical study while maintaining the validity and reliability of the findings. A total of 265 students were selected as the sample for this study using a cluster sampling technique within a survey-based approach. Further details about the population and sample distribution are provided in Table 1 below.

Table 1.
Total of classes and students as participation

Grade	Pretest	Treatment	N
	Male	Female	
Class V	21	56	77
Class IV	25	74	99
Class VI	23	66	89
Total	69	196	265

Table 1 illustrates that data were collected through the distribution of questionnaires to a representative sample of students, accurately reflecting the demographic composition of the entire population. Of the participants, 30.54% were male (69 individuals), while 69.46% were female (196). The samples were also categorized by grade level, with 32.41% from grade IV (77 students), 34.87% from grade V (99 students), and 32.72% from grade VI (77 students). For a more intuitive understanding, please refer to the following graph, which visually details this distribution.

Figure 2.
Distribution of Students by Grade and Gender



Data Collection Techniques and Instruments

Data collection techniques included surveys and tests. This study collected data on academic resilience (AR), self-regulated learning (SRL), and social studies (LO) learning outcomes using an instrument in the form of a Likert scale questionnaire adopted from previous research (Ariyani & Kristin, 2021; Turan & Koç, 2018; Ye et al., 2021). The process of developing this questionnaire was based on previous research which consisted of two separate questionnaires, namely academic resilience (AR), self-regulated learning (SRL), and social studies learning outcomes (LO).

The research instruments used to measure academic resilience, self-regulated learning, and social studies

learning outcomes comprise 31 questions. Academic resilience is assessed through key indicators such as resistance to failure, resilience under pressure, optimism, a positive outlook, and intrinsic motivation. Self-regulated learning is evaluated based on indicators including the setting of learning goals, self-monitoring, emotional regulation, and self-reflection. For social studies learning outcomes, the indicators focus on conceptual understanding, understanding of social contexts, analytical skills, critical thinking, social involvement, as well as cultural and civic awareness. Each item in the questionnaire is structured on a five-point Likert scale, allowing respondents to express their level of agreement with each statement presented. This Likert scale consists of five answer choices, namely "strongly agree" with a value of 5, "agree" with a value of 4, "somewhat agree" with a value of 3, "disagree" with a value of 2, and "strongly disagree" with a value of 1. This instrument is used to gain a better understanding of the effect of academic resilience and self-regulated learning on social studies learning outcomes of students.

Data analysis

In this study, the researchers employed the Partial Least Squares (PLS) method within Structural Equation Modeling (SEM) to analyze the interrelations among various constructs, including exogenous and endogenous variables, while accounting for measurement errors. The analysis was conducted using SmartPLS 3.0 software, which facilitated the robust testing of research hypotheses due to its advanced capabilities in handling complex models (Khine, 2013). They also took into consideration measurement errors. The analysis process was facilitated using SmartPLS 3.0 software, which helped test the research hypotheses (Mueller & Hancock, 2018). PLS-SEM is adept at modeling latent variables and their indicators, aiming to elucidate how exogenous variables influence endogenous variables through structural paths.

To ensure the accuracy and integrity of the data, the outer model (measurement model) of PLS-SEM was crucial for assessing the validity and reliability of the questionnaire indicators. The evaluation of the outer model involved stringent criteria: each indicator's loading factor needed to exceed 0.7, and the Average Variance Extracted (AVE) required a minimum value of 0.5, ensuring adequate construct validity and reliability (Al-Emran et al., 2019; Wong, 2019). These standards confirmed that the constructs were measured precisely and reliably.

Moreover, hypothesis testing within the inner model employed the p-value criterion to validate the proposed relationships. A p-value less than 0.05 indicated significant support for the hypothesis, whereas a greater value of 0.05 led to its rejection. This meticulous approach in selecting SmartPLS 3.0 was due to its efficiency in processing PLS path modeling, which is ideal for exploratory research where the primary focus is prediction and theory development.

Results

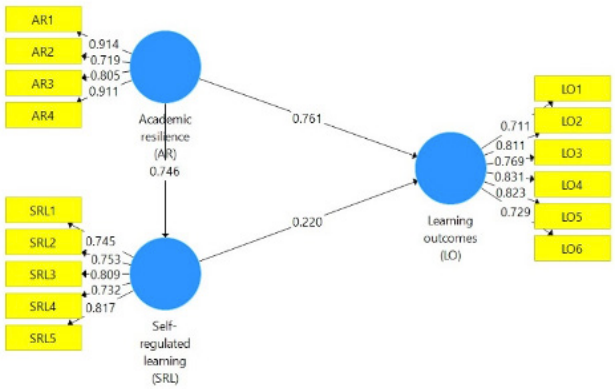
The purpose of analyzing the validity and reliability of the questionnaire for each variable is to ensure the reliability and validity of the research data. The results of the analysis show that the model meets the standards of validity (convergent and discriminant) and reliability. This study used the PLS-SEM method to analyze the results of the validity and reliability tests of questionnaires related to elementary school students. The focus of this research is on the quality of academic resilience (AR), self-regulated learning (SRL), and social studies (LO) learning outcomes in the context of the outer model. The loading factor was calculated using Confirmatory Factor Analysis (CFA) considering Cronbach's alpha, CR, and AVE values as needed. The outer model loading value for each latent variable factor exceeds 0.7 (Heale & Twycross, 2015). The results of the validity and reliability tests can be seen in Table 2 below.

Table 2.
Results of the analysis of the validity and reliability of the path model

Variable	Cron-bach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Academic resilience (AR)	0.858	0.906	0.708
Learning outcomes (LO)	0.871	0.903	0.809
Self-regulated learn-ing (SRL)	0.831	0.880	0.796

The results of the outer model analysis in Table 2 explain that all variables in this study were declared valid (0.711-0.914) and reliable (0.708-0.916). The validity test of each indicator for each variable has obtained a factor loading value above 0.7, which means it can explain the latent variables in this study. Furthermore, the reliability test obtained an AVE value above 0.5, which means that each variable is declared reliable (Lin et al., 2020). The questionnaire in this study was stated to be accurate and able to measure students' perceptions of academic resilience (AR), self-regulated learning (SRL), and social studies learning outcomes (LO) so that it could be carried out at the hypothesis stage. The results of the output of the outer model that has been carried out to analyze the validity and reliability values of the survey on academic resilience (AR), self-regulated learning (SRL), and social studies learning outcomes (LO) are shown in Figure 3 below.

Figure 3.
Path diagram of validity and reliability test results



In this study, hypotheses were proposed and tested using the path coefficient test. Before testing the hypothesis, the first step is to analyze the suitability of the research data model using the goodness of fit test. The indicators used to determine whether the model is suitable or not are the values of the normed fit index (NFI) and standardized root mean square residual (SRMR) (Adam, 2018). The SmartPLS-SEM program is used as a tool in testing the suitability of the model. The model is considered suitable if the NFI value is more than 0.8 and the SRMR value is less than 0.10. The results of the model fit analysis in this study showed that the NFI value was 0.972 and the SRMR value was 0.083, indicating that the research variable model fits the data (Hoyle, 2023; T. , Teo et al., 2013). Research hypothesis analysis was carried out using the bootstrapping test method in SmartPLS 3.0. This method aims to test a hypothesis, obtain estimates of population parameters based on the available sample, and test the significance of the proposed hypothesis. The results of the hypothesis analysis using the bootstrapping test method can be seen in Table 3 below.

Table 3.
Results of hypothesis analysis through SEM

Variable	Original Sample (O)	T-Statistics	P-Values
Academic resilience (AR) -> Learning outcomes (LO)	0.925	155.083	0.000
Academic resilience (AR) -> Self-regulated learning (SRL)	0.746	30.514	0.000
Self-regulated learning (SRL) -> Learning outcomes (LO)	0.220	6.711	0.000
Academic resilience (AR) -> Self-regulated learning (SRL) -> Learning outcomes (LO)	0.464	6.134	0.000
Academic resilience (AR) -> Self-regulated learning (SRL) -> Learning outcomes (LO)	0.536	6.334	0.000

The output results shown in Table 3 explain that the direct influence of the research hypothesis is 1) The coefficient of the academic resilience parameter (AR) on learning outcomes (LO) is 0.925, while the P-Value is 0.000 <0.05, which means that academic resilience has a positive effect on learning outcomes of 92.5%. 2) The parameter coefficient value for academic resilience (AR) on self-regulated learning (SRL) is 0.746, while the P-Value is 0.000 <0.05, which means that academic resilience has a positive effect on self-regulated learning by 74.6%. 3) The magnitude of the parameter coefficient for self-regulated learning (SRL) on learning outcomes (LO) is 0.220 while the P-Value is 0.000 <0.05 which means that self-regulated learning has a positive effect on learning outcomes by 22.0%.

The indirect effect of research can be seen from the total indirect effect which explains that the acquisition of the parameter coefficient values of all variables is equal to 0.464 and the acquisition of P-value is 0.000 <0.05, which means that the higher the AR and SRL values, the LO value will also increase around 46.4%. The overall direct effect of this study is seen from the total effect which explains that the acquisition of the R-Square coefficient of academic resilience (AR) on learning outcomes (LO) is 0.536 and the acquisition of academic resilience (AR) and self-regulated learning (SRL) values on learning outcomes (LO) is 0.877. While the acquisition of the p-value of all variables is 0.000 which means that simultaneously academic resilience and self-regulated learning have a positive and significant effect on learning outcomes with an increase of 53.6% so that the hypothesis Ha is accepted. The recapitulation results of the outer loading analysis can be seen in Figure 4 of the following path analysis.

Figure 4.
Significant path coefficient results of hypothesis testing

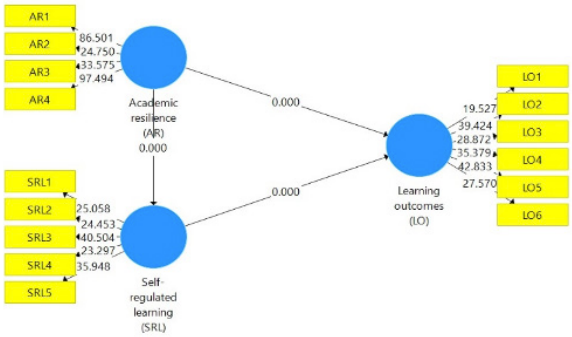


Figure 4 explains that the total p-value is 0.000, meaning that academic resilience and self-regulated learning have a significant influence on students' Social Sciences learning outcomes. Academic resilience is a student's ability to overcome obstacles and stress in learning. Students who are better able to overcome academic challenges tend to achieve better in social studies subjects. Self-regulated learning is students' ability to organize and manage their learning. Students who can organize their learning processes well, such as planning, monitoring, and evaluating, tend to achieve higher social studies learning outcomes. Academic resilience and self-regulated learning are very important and strong factors in influencing social studies learning outcomes, and this relationship does not occur by chance but is statistically significant.

Discussion

The importance of social studies learning outcomes lies in students' ability to develop a deep understanding of social, cultural, and political issues that surround them (Fauzi & Widjajanti, 2018; Feraco et al., 2022). This allows students to develop critical, analytical, and reflective thinking skills in interpreting information and making decisions related to social and cultural contexts. Academic resilience and self-regulated learning are important factors in achieving deep understanding and optimal learning outcomes in social studies learning (Cobbinah & Amoako, 2021; Uge et al., 2019).

This study has revealed a positive and significant effect of academic resilience and self-regulated learning on students' social studies learning outcomes (Fadli et al., 2024). Although both have a positive influence on student social studies learning outcomes, academic resilience is more focused on the ability to overcome stress and academic difficulties, while self-regulated learning is more focused on the ability to regulate the learning process itself (Agung Ratih Rosmilasari & Adoe, 2021; Latif & Amirullah, 2020; Syawaluddin et al., 2020). Academic resilience can help students to excel in studying social studies despite facing challenges, while self-regulated learning helps students to become more independent and effective in learning social studies (Ramdani et al., 2021; Rudd et al., 2021). Both have a positive and significant influence, academic resilience and self-regulated learning have a different role in improving student social studies learning outcomes.

Academic resilience plays a key role in helping students overcome challenges and difficulties in social studies learning. When students face obstacles such as complex material or challenging assignments, their ability to stay focused, persevere, and overcome learning obstacles becomes crucial (Aliyev et al., 2021; Liu & Han, 2022). Academic resilience helps students not to give up easily, manage stress, and motivate themselves to keep learning. Academic resilience helps students deal with problems that arise in social studies learning and still excel (L. Deng et al., 2023). In addition, self-regulated learning is also important in social studies learning outcomes. Students' ability to organize and control their learning helps them optimize the learning process (Setiani et al., 2018). Students in social studies learning need to have the ability to plan, organize, and manage their time, choose effective learning strategies, and monitor their progress (Theobald, 2021). Self-regulated learning helps students become active in social studies learning, take responsibility for their learning, and adapt their learning approach according to their needs and goals (Guo, 2022).

This study builds upon and corroborates the findings of previous research (Badrus & Arifin, 2021; Ghimby, 2022; Zahro & Surjanti, 2021; Ziadat & Sakarneh, 2022) which highlighted that academic resilience and self-regulated learning enable students to surmount learning obstacles, maintain concentration, and enhance their learning processes in social studies. These capabilities are crucial for students to develop a profound comprehension of the complex social, cultural, and political landscapes they navigate. This research supports these assertions and further enriches our understanding by demonstrating that the interplay between academic resilience and self-regulated learning helps overcome barriers and significantly enhances the depth of learning in social studies. The findings suggest that educational strategies that strengthen these skills could lead to more effective and meaningful learning outcomes. Educators and policymakers should consider integrating targeted interventions to foster these attributes within the social studies curriculum.

The importance of developing academic resilience and self-regulated learning in the social studies learning context. Teachers and education policymakers can use these findings to design learning strategies that enhance these skills (Hawkman, 2020; Heliawati et al., 2022; Jumriani et al., 2021). Efforts to strengthen student academic resilience can involve social and psychological support, developing coping strategies, and providing constructive feedback (Aliman et al., 2019; Ruhyana & Aeni, 2019). On the other hand, the development of self-regulated learning can involve teaching time management skills, using effective learning strategies, and providing opportunities for students to take an active role in social studies learning (Hamilton et al., 2021; Pattiasina & Sopacua, 2022; Yu et al., 2022).

Strong academic resilience and self-regulated learning are pivotal in optimizing the learning process, enabling students to achieve superior outcomes in social studies. When equipped with these skills, students absorb information more effectively and gain a deeper understanding of the social, cultural, and political issues pertinent to their studies (Greenberg et al., 2021). This enhanced comprehension allows them to critically analyze and contextualize this knowledge, effectively applying their learned skills and insights in real-world scenarios. As such, cultivating these attributes is crucial for students to navigate the complexities of today's global society with acumen and responsiveness (Öncü, 2024).

Consequently, social studies education must strategically focus on developing academic resilience and self-regulated learning. By doing so, educational programs can foster environments that encourage the acquisition of factual knowledge and the development of critical thinking and problem-solving skills. This approach will significantly improve student

learning outcomes in social studies, preparing them to be more engaged and informed citizens. Educational policymakers and curriculum developers should consider these factors in their instructional strategies and resource allocations to ensure that students are adequately prepared for the challenges of the contemporary world.

Conclusion

The results of this study conclude that there are gaps and limitations from previous research regarding academic resilience and self-regulated learning which affect students' social studies learning outcomes. This study found that academic resilience and self-regulated learning can have a positive and significant effect on social studies learning outcomes. The results of this study provide an important contribution in complementing our understanding of the effect of academic resilience and self-regulated learning on students' social studies learning outcomes. Previous research has provided initial insight into this relationship, but this research fills in the gaps and limitations of previous research by consistently demonstrating that academic resilience and self-regulated learning play an important role in improving student social studies learning outcomes.

These findings underscore the substantial impact of academic resilience and self-regulated learning on social studies learning contexts. Students who are adept at overcoming academic challenges, managing stress, and maintaining focus on their studies generally achieve superior outcomes in social studies. Additionally, their ability to effectively organize and control their learning processes plays a crucial role in enhancing their understanding of and ability to apply social studies concepts. Although this study provides a more comprehensive understanding of these dynamics, it is important to acknowledge its limitations. The research may be constrained by its focus on a specific demographic or educational setting. Moreover, other variables, such as motivation, environmental support, and psychosocial factors, also play significant roles in influencing social studies learning outcomes.

Future research should expand upon these findings by exploring a broader range of educational environments and demographic groups to verify the generalizability of the results. It would also be beneficial to investigate the interplay of additional factors like emotional intelligence, family background, and peer influence on learning outcomes. Further studies could also explore intervention strategies that effectively integrate academic resilience and self-regulated learning into diverse learning contexts, thereby enhancing the efficacy of social studies education across various student populations.

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Unveiling Elementary School Students' Thinking Processes in Conquering The Natural Number Bias

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Abstract

This study sought to understand how students activate number sense in determining the position of fractions on a number line and identify how the natural number bias and number sense influences students' thinking processes. The study utilized the Cognitive Task Analysis (CTA), involving four fifth-grade elementary students as the research subjects. The findings from this study suggest that students activate number sense in many ways, i.e. by comprehending the value and denominator of a fraction, dividing the number line into equal parts, and measuring distances based on fractions. However, the natural number bias could hinder students' number sense, leading to their misunderstanding of the relationship between the fraction value and denominator. This misunderstanding may result in errors in comparing fractions, adding or subtracting fractions, and solving problems involving fractions. This study contributes to understanding the role of number lines in developing students' number sense and formulating recommendations for mathematics teachers on how to identify and address the natural number

Keywords:

Natural number bias; number sense; number line; Cognitive Task Analysis (CTA)

Introduction

Understanding whole numbers and fractions is one of the fundamental challenges in elementary mathematics education. Whole numbers have simple and straightforward characteristics that are easy to understand, as each number has a distinct successor (e.g., 4 follows 3), and their values are discrete (Sun et al., 2019). In contrast, fractions are more complex because they can be represented in various equivalent forms, such as 1/2 being equal to 2/4, a characteristic that does not occur with whole numbers. This complexity often causes difficulties for students in understanding fractions, especially when asked to determine the position of fractions on a number line (Meert, Grégoire, & Noël, 2010).

Previous studies have shown that students often fall into natural number bias, which is the tendency to apply whole number concepts when dealing with fractions. This bias occurs because students tend to apply their understanding of simple whole number properties to the more complex context of fractions (Christou et al., 2020; Van Hoof et al., 2020). Natural number bias becomes evident when students incorrectly compare fractions, such as focusing only on the denominator. Students frequently assume that fractions with larger denominators have smaller values, without considering the relationship between the numerator and denominator. This misunderstanding of fraction concepts can lead to errors when comparing fractions and determining their positions on a number line (Obersteiner et al., 2016).

The use of number lines has proven effective in improving students' understanding of fraction concepts and developing their number sense (Van de Walle, Karp, & Bay-Williams, 2014). However, students' understanding of number lines is often still influenced by natural number bias, which hinders their ability to correctly place fractions. This bias arises because students tend to rely on their whole number understanding when positioning fractions on a number line, even when they possess a strong intuition about number values. For instance, students may misinterpret the proportional relationship between the numerator and denominator, relying instead on simplistic rules such as "the larger the denominator, the smaller the value," which applies to whole numbers but not fractions (Ni & Zhou, 2005).

Thus, it is important to explore how students activate their sense of number when determining the position of fractions on a number line and how natural number bias influences their thinking processes. Understanding these patterns will provide insights into the cognitive mechanisms behind students' errors and can inform effective teaching strategies that target and reduce natural number bias in fraction learning.

This study aims to explore students' thought processes in placing fractions on a number line and to analyze the influence of natural number bias on their number sense. By understanding these patterns, it is hoped that the results of this research can provide more effective recommendations for mathematics teachers to address natural number bias and enhance students' understanding of fractions.

This study seeks to answer two main questions:

1. How do students activate their number sense when determining the position of fractions on a number line?

2. How do natural number bias and number sense influence students' thought processes?

Literature Review

The Whole Number Bias and Natural Number Bias

The whole number bias refers to students' tendency to apply whole number concepts when working with fractions, a phenomenon that has been observed at various levels of education, from elementary school to university (Christou et al., 2020; Obersteiner et al., 2016; Van Hoof et al., 2020). This bias becomes particularly evident when students are asked to compare simple fractions with the same numerator. In these instances, students influenced by whole number bias tend to assume that the fraction with the larger denominator has the larger value, neglecting the proportional relationship between the numerator and denominator. This phenomenon arises from students' excessive focus on one element of the fraction typically the denominator (Vamvakoussi et al., 2012).

While whole number bias primarily involves using whole number logic to interpret fractions, a more fundamental cognitive challenge students face is rooted in the natural number bias. Natural number bias is a more general cognitive tendency where students over-rely on their intuitive understanding of whole numbers (natural numbers) when confronted with fractions. In simple terms, students apply their natural number understanding to fractions, assuming the rules and patterns of whole numbers apply universally, even in the context of more complex fraction relationships.

The natural number bias in fractions becomes especially evident when students try to compare or position fractions. For instance, when comparing fractions like 1/3 and 1/5, students influenced by natural number bias might wrongly assume that 1/5 is larger because the numerator is numerically smaller, even though the actual value of 1/3 is larger. Similarly, when fractions with different numerators are compared, students might still cling to the belief that the fraction with the larger numerator is always larger, much like with natural numbers (Obersteiner et al., 2013).

The natural number bias is reinforced when students use fractions with numerators or denominators that are easy to understand, such as 1/2, or simple multiples of 1. These simplified fractions often encourage students to focus on whole number differences, rather than truly understanding the proportional nature of fractions. To address this bias, research suggests that more complex fractions, with varied numerators and denominators, should be used in teaching. This approach would allow for a deeper examination of how natural number bias affects students' understanding of fractions (Van Hoof et al., 2020).

Students who are prone to natural number bias are more likely to make errors when comparing fractions that do not align with whole number relationships.

For example, when comparing 2/9 and 1/4, students influenced by natural number bias may make errors, assuming the larger denominator means a smaller value, ignoring the relational dynamics between the numerator and denominator (Deliyianni et al., 2016). These errors reflect the cognitive gap between students' whole number logic and their ability to grasp fractional equivalence and relative values.

A better understanding of natural number bias and its impact on fraction comparison processes is crucial for educators. This understanding will help educators design more effective teaching strategies that enable students to overcome their reliance on whole number reasoning. By focusing on the specific challenges that natural number bias presents, teachers can help students improve their conceptual understanding of fractions. One recommended strategy is the use of various fraction representations, such as number lines, which allow students to visualize the relationships between fractions and see beyond the whole number-based assumptions that may be clouding their understanding (Michaelidou & Gagatsis, 2005).

Though natural number bias is a widespread cognitive challenge, the degree to which this bias diminishes over time is a subject of ongoing debate. Some researchers argue that exposure to more fraction concepts over time gradually reduces natural number bias (Van Hoof et al., 2015). However, studies show that this bias does not significantly decrease in students until later grade levels. For example, natural number bias may still be prevalent in 4th and 6th graders, but it diminishes gradually in higher grades, such as in 8th graders, who demonstrate a better understanding of fractions that are not governed by whole number rules. Notably, experts in mathematics do not exhibit natural number bias, further indicating that this bias can be overcome with deeper understanding and experience (Obersteiner et al., 2013).

The consequences of natural number bias are significant and long-lasting. If students do not grasp the fundamental principles of fractions early on, they are more vulnerable to this bias, which can persist for years. Even students who have learned the procedural rules for fraction operations may still struggle with conceptual understanding, leading to difficulties in more advanced mathematical topics that involve fractions (Deliyianni et al., 2016). To address these issues, number lines are often employed to evaluate and reduce natural number bias. By visually representing fractions on number lines, students can better understand the proportional relationships that underlie fractional values and how these relationships differ from the properties of whole numbers. A systematic and structured approach, along with appropriate visual tools, will help educators identify natural number bias in students' thinking and take steps to overcome it, ultimately fostering a deeper understanding of fractions and providing a strong foundation for future mathematical learning.

Number Lines: Unlocking Number Sense and Overcoming Natural Number Bias

Number lines have long been recognized as an effective tool for helping students visualize mathematical concepts, including fractions. With number lines, students can directly observe the relationship between the value of a fraction and its position within a numerical range, enabling them to develop number sense or number intuition. A strong number sense is a critical foundation for deeper mathematical understanding and the ability to solve problems involving numbers (Van de Walle, Karp, & Bay-Williams, 2014).

Despite their great potential, many previous studies have focused on the effectiveness of number lines in strengthening students' conceptual understanding of fractions (Barbieri et al., 2020; Rahayuningsih et al., 2025; Rahayuningsih et al.,2021) without specifically exploring how natural number bias affects students' ability to place fractions on a number line. Natural number bias, the tendency of students to apply whole number logic when working with fractions, remains a significant obstacle in mathematics education (Christou, Pollack, Van Hoof, & Van Dooren, 2020; Obersteiner, Van Hoof, Verschaffel, & Van Dooren, 2016). This bias becomes evident in the context of number lines when students struggle to place fractions correctly. Students influenced by natural number bias may incorrectly divide the number line or fail to understand the relationship between the numerator and denominator, leading to errors in fraction placement (Vamvakoussi, Van Dooren, & Verschaffel, 2012).

This study aims to address this gap by deeply exploring how students activate their number sense through number lines and how natural number bias influences their thought processes in determining the position of fractions. The study emphasizes the use of number lines not only as a visual aid but also as a diagnostic tool that can identify students' conceptual errors caused by natural number bias. By doing so, the research provides a new contribution to the field of mathematics education by linking the role of number lines with an analysis of students' thought processes related to natural number bias.

The novelty of this study lies in its systematic focus on understanding the interaction between number lines, number sense, and natural number bias. Unlike previous studies that have assessed the general effectiveness of number lines in teaching fractions (Barbieri et al., 2020), this research offers new insights into how number lines can be strategically used to overcome natural number bias and improve students'

understanding of fraction positions on a number line. The results of this research are expected to provide a strong foundation for developing more effective and targeted teaching strategies in the future.

Methods

Design and Research Setting

This study uses the Cognitive Task Analysis (CTA) approach to investigate students' thought processes in understanding the position of fractions on a number line and to analyze the influence of whole number bias on their understanding. CTA was chosen because it effectively breaks down complex thought processes into more structured and systematic stages (Clark et al., 2008). CTA has been widely applied across various fields, including education, to understand individuals' cognitive behavior when completing tasks that require deep thinking (Schraagen et al., 2000; Merriënboer, 2010). However, its application in elementary mathematics education, particularly related to whole number bias, remains limited, giving this study its novelty.

The initial phase begins with gathering preliminary information. This information is obtained through a literature review focusing on previous studies about whole number bias (Christou et al., 2020; Van Hoof et al., 2020) and the importance of number sense in understanding number lines (González-Forte et al., 2022; Van de Walle et al., 2014). In addition, the researcher conducts exploratory interviews with elementary mathematics teachers at the research site. These interviews aim to gather information about the characteristics of students prone to whole number bias, indications of difficulties students face in placing fractions on a number line, and the teaching strategies teachers have used to address these issues. This approach aligns with Schraagen et al. (2000), who emphasize the importance of understanding the context before starting cognitive analysis.

Based on the preliminary information, the second phase is identifying students' knowledge representations. At this stage, the researcher develops a conceptual framework that maps the stages of students' thought processes when solving fraction tasks. This framework includes four main components: understanding the problem, selecting solution strategies, applying mathematical operations, and evaluating answers. This analysis focus aligns with the systematic approach of CTA, which aims to identify the skills and knowledge underlying individual performance (Clark et al., 2008). To validate this framework, the researcher designs an instrument consisting of fraction tasks specifically structured to trigger whole number bias. The tasks include comparing fractions with different denominators and placing fractions on a number line, such as asking students to determine the positions of 2/3 and 3/5 on the same number line (Meert, Grégoire, & Noël, 2010).

The next phase, eliciting focused knowledge, is conducted using the think-aloud protocol technique. This technique allows students to verbally express their thought processes while completing the given tasks. In practice, students are asked to divide the number line into appropriate segments, place fractions in specific positions, and explain the logic they used. The think-aloud method was chosen because it is effective in uncovering students' real-time and in-depth thought processes (Ericsson & Simon, 1993). During these sessions, the researcher provides minimal instructions, such as "Tell me what you are thinking when dividing this line" or "Why did you choose this position for the fraction?" to encourage students to articulate their reasoning. This open-ended approach allows the researcher to capture authentic, unfiltered insights into students' cognitive strategies.

After the think-aloud session, the researcher conducts semi-structured interviews to further explore the strategies students used, the challenges they faced, and indications of natural number bias (as well as any other relevant cognitive biases). The interview instrument was validated through expert judgment by two mathematics education experts, who reviewed the clarity, appropriateness, and alignment of the questions with the study's objectives (Creswell & Miller, 2000). To ensure the reliability of the instrument, it was tested through trials with students outside the study participants. This additional step was essential to assess whether the instrument consistently measured the intended constructs across different individuals and contexts, ensuring that the questions were appropriately understood and the data collected would be reliable.

The fourth phase involves data analysis and verification. The think-aloud and interview recordings are transcribed and analyzed using thematic analysis to identify thought patterns, common strategies, and indications of whole number bias (Braun & Clarke, 2006). The analysis focuses on how students understand the relationship between the numerator and denominator in the context of number lines and how whole number bias influences their decisions. Data triangulation is conducted by comparing transcripts, direct observations, and student task results to ensure the consistency of findings. The researcher also performs member checking with participants, where preliminary analysis results are shared with students to validate the accuracy of the interpretations made by the researcher (Stalmeijer et al., 2014).

In the final phase, developing a thought process model, the analysis results are used to construct a model that illustrates the stages of students' thinking when solving

fraction tasks on a number line. This model visualizes how whole number bias emerges in students' thought processes and the role of number sense in helping them understand the relative values of fractions. The model is presented as a descriptive narrative and flowchart that can be used by teachers as a guide to identify and address whole number bias in the classroom. Additionally, this study provides practical recommendations for mathematics teachers to integrate number lines effectively as a teaching tool, using a more concrete and interactive approach (Van de Walle et al., 2014).

Throughout this study, ethical procedures are implemented in adherence to responsible research principles. Student participation is carried out with written consent (informed consent) from parents and students, after they receive detailed explanations about the study's objectives, procedures, and participants' rights. Students' data confidentiality is strictly maintained, and the right to withdraw participation without consequence is explicitly stated. With this approach, the research is conducted ethically, systematically, and with a focus on students' needs and real-world contexts.

The research instrument consists of a fraction estimation task on a number line designed to explore students' understanding of placing fractions and to identify indications of whole number bias. The instrument design is adapted from previous studies focusing on using number lines as a tool to understand fraction values (Iuculano & Butterworth, 2011; Meert, Grégoire, & Noël, 2010). In this study, the instrument is systematically developed, starting from preparation, implementation, to the validation process, to ensure it possesses adequate validity and reliability.

The instrument consists of a 20 cm number line on A4 paper, marked with 0 on the left end and 1 on the right end, representing the range of fractions used in the tasks. Additionally, the researcher prepares fraction cards containing 15 target fractions that have been predetermined. These fractions include:

- Values less than 1 to focus students on parts of a whole,
- Denominators varying from 2 to 10, with an additional denominator of 20,
- Equivalent fractions, such as 1/1, 2/2, 3/3, 4/4, to test the understanding of fractions representing 1.
- Target fractions such as 4/9, 1/2, 4/5, 3/4, 4/8, 1/6, 1/3, 5/6, 1/4, 8/10, 1/20, 3/5, 5/8, 3/6, and 5/7 are chosen to create task complexity variation. This variation allows the researcher to observe the consistency of students' understanding and the extent to which whole number bias influences the strategies they use.

The task is carried out individually in the following stages: (1) The researcher provides simple verbal instructions to students to estimate the position of fractions on a number line; (2) Each fraction card is shown one at a time, and students are asked to mark the position of the fraction on the number line using a pencil; (3) The marked positions are recorded on a data sheet by the researcher, and observations are conducted to note students' behavior during the marking process.

To ensure the instrument's validity and reliability, the researcher conducts a validation process, including content validity and instrument reliability. Content validity is tested through expert judgment involving two mathematics education experts and one elementary school mathematics teacher. This evaluation aims to assess the extent to which the instrument measures the research objectives, namely: (1) Students' understanding of fraction values; (2) Activation of students' sense of number; and (3) Indications of whole number bias in determining the position of fractions. The experts provide feedback regarding: (1) Clarity of instructions; (2) Relevance of the fraction cards to the research objectives; and (3) Task complexity level appropriate for fifth-grade students.

The results of the expert evaluation are analyzed using Aiken's V to calculate the instrument's validity score. The obtained Aiken's V value is 0.85, indicating high validity (Azwar, 2015). This value exceeds the minimum threshold of 0.70, meaning the instrument is appropriate for use in the study.

Subsequently, the instrument's reliability is tested through a field trial with fifth-grade students who are not part of the study participants. This trial aims to assess the consistency of students' responses in marking the position of fractions on the number line. The trial data is analyzed using reliability coefficients through the test-retest method, and a reliability score of 0.82 is obtained. This value indicates good reliability, as it exceeds the 0.70 threshold (Creswell, 2014).

With high content validity and good reliability, this instrument is of sufficient quality to reveal students' thought processes in placing fractions on a number line. Furthermore, this instrument was developed contextually based on previous studies proven effective in identifying students' understanding and indications of whole number bias (Meert et al., 2010; Van Hoof et al., 2020).

The validation and reliability testing processes ensure that the instrument can be accurately used to evaluate students' understanding of fraction positions and provide consistent data within the context of this study. Thus, this instrument serves not only as a measurement tool but also as an in-depth exploration

tool for identifying students' thought patterns and challenges in understanding the concept of fractions.

Data Analysis

Data collection and analysis were conducted systematically and iteratively, using a triangulation approach and validation through member checking to ensure the accuracy of data interpretations. Member checking was carried out by verifying the research findings with the study participants, allowing data interpretations to be directly confirmed by their sources (Creswell & Miller, 2000; Stalmeijer et al., 2014). The data analysis used in this study is comprehensive, aiming to uncover in depth the thought processes of students experiencing whole number bias and how their sense of number plays a role in solving fraction problems.

The data analysis process began with student data, focusing on the transcription of audio recordings from the think-aloud protocol sessions. These transcriptions were analyzed using thematic analysis (Braun & Clarke, 2006) to identify patterns, themes, and categories in students' thought processes. The main themes identified included: problem-solving strategies, understanding of fraction concepts and number operations, and the influence of whole number bias on students' thinking. In this process, each student response was coded to map similarities and differences in the approaches used. For example, students with whole number bias tended to focus on the denominator's value as the determinant of magnitude, while students with a strong number sense were more likely to compare the relationship between the numerator and denominator.

The initial analysis results were then verified through member checking, where the researcher discussed preliminary findings with several study participants. Through member checking, the researcher ensured that data interpretations matched the actual experiences expressed by the students. This step is crucial for enhancing the credibility of the data obtained (Creswell & Miller, 2000). Additionally, data triangulation was conducted, where data from multiple sources, including think-aloud sessions, student interviews, direct observations, and task results, were compared and integrated. This triangulation helped the researcher build a more comprehensive and valid understanding of students' thought processes when tackling fraction tasks.

After analyzing student data, teacher data were analyzed, focusing on interviews with mathematics teachers. This analysis aimed to understand teachers' perspectives on the occurrence of whole number bias in the classroom and the instructional strategies they implemented to help students overcome this bias. Teacher interviews were analyzed using a similar thematic approach, focusing on teachers' experiences in: (1) identifying whole number bias among students, (2) teaching strategies used to improve students' understanding of fractions, and (3) teachers' efforts to develop students' number sense through number-line-based approaches.

Results

How students activate number sense when determining the position of fractions on a number line

Case Analysis

The following cases will illustrate fascinating examples of the results of a mathematics learning project on fractions. These cases are centered around the problem-solving processes employed by three students who activated their number sense when dealing with fractions.

> *Case 1:*
>
> *"On a number line, Student 1 placed 4/9 in the left side of ½. The value of 4/9 is smaller than 1/2 because the denominator is larger. When a number line is divided into 9 parts, then 4/9 represents four of nine segments. The position of the fraction will be between 0 and 1/2, closer to 0. Student 1 may be inclined to choose the fraction with the smaller denominator or a value closer to 0 or 1, even though the fraction does not fit the problem. The decision made by the student may be due to his familiarity with the whole numbers and it is easier to understand fractions with smaller denominators. When asked to find a fraction smaller than 1/2, the student chose 1/3 rather than 4/9, even though the value of 4/9 is smaller than 1/3. The student may be trapped by the simple rule that "the larger the denominator, the smaller the value". The student neglected the fact that this rule is only applicable when the numerators are the same."*
>
> *Case 2:*
>
> *"Student 2 was trying to put 3/5 on a number line. First, he divided the number line into five equal parts, where the third part starts at 0 and is 3/5 of the total length of the number line. When measuring the distance from 0 to 1, 3/5 is located at the point that is 3/5 of the way. However, when the student was asked to compare ¾ and 5/6, he would say that 5/6 was greater than ¾ since the denominator is larger although ¾ is larger in value."*
>
> *Case 3:*
>
> *"According to Student 3, 1/1 is an interesting fraction because the denominator and numerator are the same, namely 1. On a number line, 1/1 is located at the far right, namely at point 1. This shows that 1/1 represents a whole, just like the number 1. When asked to find a fraction that represents a whole, Student 3 chose 1/1, even though other fractions such as 10/10 or 20/20 also represent a whole.*

Focusing on the denominator is one of the common misconceptions that often occurs when students learn fractions. The tendency for students to assume that fractions with larger denominators have smaller

values is a simplification that is not always true. When students only focus on the size of the denominator without considering the numerator, they often make incorrect conclusions. For example, when comparing 4/9 and 1/2, students may automatically assume 4/9 is smaller because 9 is greater than 2. However, in the illustration where a cake is divided into 9 pieces, 4 pieces of 9 are certainly larger than half of the cake. This misconception indicates that students do not fully understand the concept of fractions in depth. To overcome this, it is important for educators to emphasize that both the numerator and denominator play an important role in determining the value of a fraction. The use of concrete models such as pictures or real objects can help students visualize the concept of fractions and compare them more effectively. In addition, sufficient practice in comparing fractions with different denominators is also very important to strengthen students' understanding of fractions.

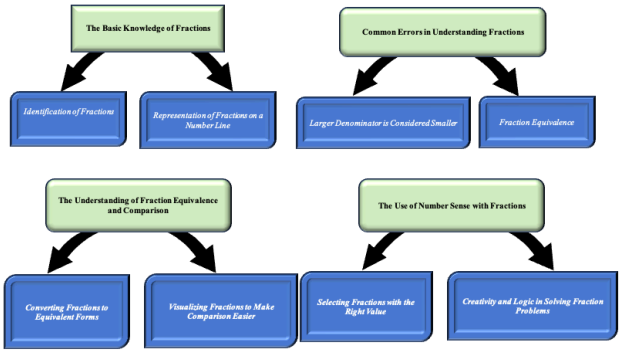
The difficulties faced by students when comparing fractions with different denominators often arise due to a lack of basic understanding of fractional equivalence and how to convert fractions into equivalent forms. When dealing with two fractions with different denominators, students tend to fall into the simple assumption that the fraction with the larger denominator is always greater. In fact, to be able to compare two fractions accurately, students need to convert them into fractions that have the same denominator. The process of converting fractions into equivalent forms involves an understanding of the concepts of multiples and Greatest Common Divisor. A lack of understanding of these concepts often hinders students in solving fraction comparison problems. In addition, difficulty in visualizing the equal parts of two different wholes can also make it difficult for students to compare fractions. In other words, students may struggle to imagine how ¾ of one pizza compares to 5/6 of another pizza. Therefore, the use of visual models such as pie charts or number lines can greatly assist students in understanding this concept. In addition, it is crucial for students to engage in sufficient practice to enhance their comprehension of determining the denominator of Least Common Multiple and converting fractions into equivalent forms.

A common challenge encountered by students when comprehending fractions is associated with the representation of the whole. Students frequently focus on the general form of a fraction, which is a/b, and assume that the denominator and numerator must be different. As a result, they only know fractions such as 1/2, 3/4, or 5/6 as representations of smaller parts of a whole. In fact, fractions can also be used to represent whole parts or wholes. For example, when asked about a fraction that represents an entire pizza, many students will immediately answer 1/1. They tend to ignore other possibilities such as 2/2, 3/3, or even 10/10 which also represent the entire pizza. This misunderstanding shows that students do not fully understand that a fraction is a comparison between a part and a whole, and that the value of a fraction does not always have to be less than one.

This misunderstanding stems from students' initial understanding of whole numbers, in which larger numbers are associated with larger values. However, this concept does not always apply to fractions. Failures in addressing this misconception might impede students' understanding of more complex fraction operations, such as adding, subtracting, multiplying, and dividing fractions.

The students' answers to the fraction problem in this study showed how they activated their number sense to understand fractions and place them on a number line. Student 1 understood the concept of value and denominator of fractions to determine which was smaller than ½. On the other hand, Student 2 was able to comprehend how to divide a number line into equal parts and measure distance based on fractions. Student 3 possessed knowledge of the relationship between 1/1 and the number 1, as well as its position on a number line. These three cases demonstrated that students with strong number sense could solve problems involving fractions and number lines in creative and logical ways. Figure 1 is a diagram pattern that illustrates how students activate their number sense when determining the position of fractions on a number line.

Figure 1.
Students' Thinking Process in Understanding Fractions



1. The Basic Knowledge of Fractions

Understanding fractions begins with a clear grasp of their components and their representation on a number line. One of the first challenges students face is identifying fractions. Often, students focus on the denominator of a fraction and mistakenly assume that the fraction with the larger denominator always represents a smaller value. For example, when asked to compare 1/3 and 1/4, students influenced by this misconception might assert that 1/4 is larger because its denominator is larger, even though 1/3 is actually the larger fraction.

The representation of fractions on a number

line is another essential step in building fraction understanding. In this process, students use number lines to determine where fractions are positioned by dividing the line into equal parts. For instance, when placing 1/2 on a number line, students must divide the line into two equal parts and locate 1/2 exactly halfway between 0 and 1. However, many students find this challenging, especially when the fractions have more complex denominators.

2. Common Errors in Understanding Fractions

Among the most common errors in fraction comprehension is the assumption that fractions with larger denominators are always smaller. This larger denominator means smaller value misconception arises from students' reliance on their understanding of whole numbers, where larger numbers are seen as greater. For instance, students may incorrectly assume that 1/5 is smaller than 1/2, simply because 5 is larger than 2.

Another frequent misunderstanding involves fraction equivalence. Students often struggle with the concept that fractions with the same numerator and denominator represent the same value, such as 2/2, 3/3, and 4/4 all equating to 1. This inability to recognize equivalent fractions hinders their understanding of how fractions relate to each other.

3. The Understanding of Fraction Equivalence and Comparison

An important skill for fraction comparison is the ability to convert fractions to equivalent forms. For example, when comparing 1/2 and 2/4, students need to recognize that these fractions are equivalent. Converting fractions to have the same denominator allows students to more easily compare their sizes. In this way, converting fractions to equivalent forms is an essential step in fraction comparison and understanding.

Visual aids like pie charts and number lines can be extremely helpful in making this comparison easier for students. By visualizing fractions, students can see their relative sizes more clearly. For example, a pie chart representing 1/2 versus 2/4 shows that both fractions cover half of the whole, reinforcing the concept of equivalence. These visual tools help students move beyond rote learning and develop a deeper understanding of fraction relationships.

4. The Use of Number Sense with Fractions

Students with strong number sense can use logic to determine the relative value of a fraction, even when the fractions are not expressed with the same denominator. For instance, when asked to compare 3/5 and 2/3, a student with well-developed number sense can recognize that 3/5 is larger, even though the fractions have different denominators, by understanding the proportional size of the fractions on a number line.

Moreover, students apply creativity and logic in solving fraction problems. Strong number sense allows them to explore different strategies for solving fraction-related problems. For example, students might use strategies like finding common denominators or using visual tools to help solve addition, subtraction, or comparison problems involving fractions. The ability to approach fraction problems in creative ways not only strengthens their understanding but also builds their problem-solving skills in mathematics more broadly.

How the natural number bias hinders the thinking processes of students with strong number sense, leading to incorrect responses to the fraction problem

A task involving fractions stated that there is a number line with 10 equal parts. Students were asked to place 3/4 on the number line. Students with strong number sense could understand that 3/4 represents 3 of the 4 equal parts on the number line. However, these students showed a simplicity bias. They were tempted to place 3/4 in the middle of the number line, as this is the simplest and easiest way to remember position. Then, they placed 3/4 in the 5th part of the number line, right in the middle. In other words, they focused on the simplicity of the position rather than the actual value of the fraction. These students assumed that 3/4 should be placed in the middle because it is "half" of 4 parts. This case strongly suggests that the natural number bias can hinder students' ability to solve fraction problems accurately, although they possess strong number sense.

When comparing 1/3 and 2/5, students with strong number sense could comprehend that fractions represent parts of a whole. They could divide whole numbers into equal parts and understand the relative value of fractions. However, these students had difficulty solving the problem due to the natural number bias. They concentrated more on the denominator of the fraction than on its value and assumed that the fraction with the larger denominator always has a larger value. These students mentioned that 2/5 was greater than 1/3 because the denominator was larger (5 > 3). They merely focused on the denominator of the fraction (5 and 3) rather than its values (1/3 and 2/5). Therefore, they failed to consider that, compared to 1/3, 2/5 represents a larger part of the whole.

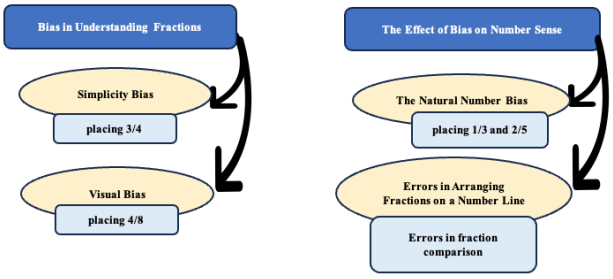
Student biases might lead to a misinterpretation of the correlation between fraction values and their denominators. This misinterpretation can result in errors in comparing, adding, or subtracting fractions as well as solving problems that involve fractions.

A math problem reads: "A number line has 10 equal parts. Place the fraction 4/8 on the number line." Students with strong number sense would understand that 4/8 represents 4 of 8 equal parts on a number line. They would divide a whole number into equal parts and understand the relative value of fractions. However, the students' ability to solve the problem might be hampered by visual bias. Students relied on the visual representation of the number line to understand fractions, but they did not always understand the relationship between the distance on the number

line and the value of the fraction. As a result, students placed 4/8 in the 4th section of the number line, right in the middle. Students focused on the equal distance on the number line for each section. Students assumed that 4/8 should be placed in the 4th section because it is the "middle" of the 8 sections. Visual bias can lead to students misinterpreting the relationship between the value of a fraction and its visual representation on the number line. This misinterpretation of fractions can result in inaccuracies when arranging fractions on a number line, comparing fractions, and solving problem involving fractions.

Figure 2 presents a diagram that illustrates the influence of the natural number bias on students' understanding of fractions and use of number sense. This diagram depicts the different types of bias that affect students' understanding of fractions and how they can lead to errors in solving fraction problems.

Figure 2.
The Impact of Bias on Fraction Understanding and Number Sense



1. Bias in Understanding Fractions

A common tendency among students is to place fractions in positions that seem simpler to them, even when those positions do not correspond to the correct fractional values. For example, when asked to place 3/4 on a number line, many students place it directly in the middle of the segment between 0 and 1. This happens because they perceive it as the "simplest" fraction close to 1, even though the actual value of 3/4 is slightly less than 1. Students tend to apply this simplicity bias without considering the precise relationship between the numerator and the denominator, leading to misplacement on the number line.

Visual Bias: Another observed bias is the visual bias, where students rely heavily on the visual representation of fractions on the number line but fail to understand how the distance between points corresponds to the value of the fraction. For instance, when placing 4/8 on the number line, students may incorrectly position it in the 4th place of the 8 equal divisions, simply because they see it as "in the middle" without considering that 4/8 is equivalent to 1/2 and should be placed halfway between 0 and 1. This bias suggests that students often misinterpret the visual cues from number lines without a full understanding of the fractional value they represent.

2. The Effect of Bias on Number Sense

The Natural Number Bias: Natural number bias occurs when students mistakenly apply their understanding of whole numbers to fractions. For example, when comparing 1/3 to 2/5, many students believe that 2/5 is larger because 5 is greater than 3, assuming the fraction with the larger denominator must always have a smaller value, just like with whole numbers. This misconception leads students to incorrectly compare fractions based solely on the size of the denominator, rather than understanding the true proportional relationship between the numerator and denominator.

Errors in Arranging Fractions on a Number Line: Errors in arranging fractions on a number line are common and often stem from the biases discussed above. For example, when asked to compare 1/2 and 3/4, students influenced by natural number bias might incorrectly place 1/2 further to the right of 3/4 simply because 1/2 is perceived as smaller based on their intuitive understanding of whole numbers. These misplacements and errors in comparison can lead to a lack of understanding of fraction size and their relative positions on the number line, hindering students' ability to make accurate fraction comparisons.

Discussion

The present study sought to understand how students activate their number sense when determining the position of fractions on a number line and identify how the natural number bias and number sense affect students' thinking processes. The results of this study are corroborated by past studies demonstrating that both whole numbers and fractions have different characteristics and require different cognitive involvement in determining them on a number line (Klein et al., 1998).

The findings of this study suggest that fraction value estimation develops differently from whole number value estimation. According to a study by Yuan and Chen (2020), 41.3% of fourth graders adopted a nonlinear model in fraction estimation, while 21.2% of fifth graders demonstrated a linear estimation pattern. These findings indicate that fraction value estimation develops from a nonlinear to a linear pattern. Similarly, (Braithwaite & Siegler, 2018) reported that fraction estimation on a number line can be used to assess whole number bias. Furthermore, (Namkung & Fuchs, 2016) revealed that attention and processing speed were significant predictors for whole numbers and fraction calculations. These results align with the findings in the first study which showed that attention to the concept of fractions may reduce whole number bias.

Case 1: Student 1 placed the fraction 4/9 to the left of 1/2, demonstrating an understanding that 4/9 is smaller than 1/2. This shows that the student understood that the numerator and denominator

of a fraction can affect its relative value. This understanding is in line with cognitive development theory, where children at the concrete operational stage begin to understand mathematical concepts through the manipulation of concrete objects. In line with the results of research conducted by Judd and Klingberg (2021), spatial cognitive training, especially working memory and visuospatial reasoning, has a significant impact on mathematics learning in children aged 6-8 years. Furthermore, Fyfe et al. (2015) mentioned that fading concreteness, where problems are presented with concrete material and fade into abstract representations, is beneficial for children's understanding of mathematical concepts.

Case 2: Student 2 chose 3/5 and was able to divide a number line into 5 equal parts. Student 2, however, made an error when comparing 3/4 and 5/6 by stating that 5/6 is larger because its denominator is larger. This error can be explained by the theory of "whole number bias," in which children are more likely to rely on more familiar whole numbers than on more abstract fractional values. Children's difficulties with fractions and rational numbers are associated with their knowledge of whole numbers (Ni & Zhou, 2005).

Case 3: Student 3 showed a good understanding of the fraction 1/1 representing the whole, but only chose 1/1 as the representation of the whole without considering other fractions such as 10/10 or 20/20. According to Siegler's conceptualization theory, children tend to use the simplest and most familiar examples to understand new concepts (Siegler & Pyke, 2013)

Natural number bias is the tendency of students to use whole numbers as the primary reference in understanding and processing fractions. The natural number bias can hinder students' deeper understanding of the relative value of fractions. According to the dual process theory of Kahneman (2011), students often use "system 1" (fast and intuitive thinking) than "system 2" (slow and analytical thinking) when processing fractions.

The results of this study are in line with the findings of Van Hoof et al. (2015) which concluded that the whole number bias in fraction estimation takes 4 years to fade. However, in this study, half of the students managed to correct their whole number bias within one year. This could happen due to a more effective teaching method in introducing the concept of fractions to students. Mazzocco et al. (2013) suggested that students with low mathematical scores may learn fractions from one and a half parts first with a gradual shift to more difficult fractions. These students have the potential to achieve the same level of performance as high-achieving students withing a year.

The current study also found that the nonlinear group exhibited a clear whole number bias in estimating unit fractions and equivalent fractions. However, in experiments involving fractions with the same denominator, students did not estimate large values when the target fraction had a large numerator. This suggests that the estimation behavior of nonlinear group fractions is mainly influenced by their denominators. This finding supports the results of the study conducted by Braithwaite and Siegler (2018).

To address bias in fraction learning, teachers need to apply various learning approaches that can help students develop a deeper understanding of fractions. Theory from research conducted by Getenet and Callingham (2021) suggests that teachers should focus on connecting constructs and procedures and forming classroom discussions that support students' learning about fractions. For example, teachers can use concrete property, such as pieces of paper divided into equal parts, to help students understand the relative value of fractions.

Multisensory learning approaches, as proposed by Dewey's active learning theory, can help students overcome visual and natural number biases (Crollen et al., 2019). By using a variety of media and props, students can develop a more holistic understanding of fractions. For example, using a number line that can be touched and physically manipulated can help students understand the relationship between the value of a fraction and its position on the number line.

Conclusion

The findings from this study indicate that students may experience various difficulties and misinterpretations in understanding the concept of fractions, especially in the context of positioning fractions on a number line. Although students demonstrate strong number sense with fractions, they are often trapped in biases related to whole numbers that can interfere with their understanding of the value and comparison of fractions.

First, this study has identified that students tend to assume that fractions with larger denominators always have smaller values, indicating a lack of in-depth understanding of the interaction between the numerator and denominator in fractions. This is seen in their tendency to compare fractions based on the value of the denominator alone, without evaluating the numerator.

In addition, students frequently face difficulty recognizing fractions that also represent whole numbers, such as 1/1, 2/2, or 3/3. Students typically comprehend 1/1 as a representation of a whole and do not realize that other fractions can also represent the same value.

This study also highlights the importance of using concrete and visual models in teaching fractions. By utilizing appropriate teaching models and tools, students can better understand the relationship between fraction values, their position on a number line, and how to compare fractions more accurately. Discussions that involve repetition of concepts and additional practice in comparing fractions are essential to reinforce this understanding.

In summary, this study recommends that educators should focus on managing and reducing bias in fraction learning, by integrating multisensory approaches and utilizing concrete objects to help students develop a more comprehensive and in-depth understanding of fractions. In this way, students are expected to overcome the difficulties they face when dealing with fractions and build a strong foundation for comprehending fractions and more complex mathematical operations in the future.

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Self-Efficacy Meets Creativity: How the Dual Moderating Roles of Intrinsic and Extrinsic Motivation Shape Innovative Outcomes

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Abstract

Despite the growing emphasis on the role of creativity, the underlying mechanisms associating self-efficacy and creativity with certain mediating roles remain partly ambiguous. Generally defined as having the skill to make something new and original, creativity is commonly acknowledged as a construct having many ties in common with several realms. This study aims to discover its relationship with self-efficacy through the mediating roles of intrinsic and extrinsic motivation. The Marmara Creative Thinking Dispositions Scale, The Academic Self-Efficacy Scale, and The Academic Motivation Scale were used for collecting the data and they were administered to a total of 197 participants attending a university in İstanbul in the academic year of 2023-2024. The study followed a quantitative approach and mediation analysis was employed to examine the mediating roles through Structural Equation Modeling (SEM). The findings revealed that except for the link between creativity and extrinsic motivation, intrinsic motivation and self-efficacy correlated with creativity in a positive and significant way. As for the mediating roles, while there was a positive and significant effect of intrinsic motivation on the relationship between self-efficacy and creativity (β = 0.155, t = 0.664, p < 0.01), a significant but negative mediating role of extrinsic motivation (β = -0.064, t = -2.096, p < 0.05) was observed. The practical implications and interpretations of the findings are further discussed.

Keywords:

Creativity, self-efficacy intrinsic motivation, extrinsic motivation, moderating effect

Introduction

The exponential growth in the complexity of today's professional and academic world has urged individuals to promote the ability to think creatively (Cropley, 2022; Hernández-Torrano & Ibrayeva, 2019) in that creativity enables individuals adapt new settings, find suitable solutions for challenging tasks and generate new opportunities for new avenues for development (Hughes et al., 2018). Defined as "the ability to make or otherwise bring into existence something new, whether a new solution to a problem, a new method or device, or a new artistic object

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or form" (Encyclopedia Britannica, n.d.), creativity is acknowledged as an important human attribute for societal, technological and financial aspects (Haigh, 2010) and as a valuable field of interest (Kerr & Stull, 2019; Ma et al., 2024). Many researchers who have remarked on the definition of the concept of creativity consented that the term contains two fundamental components: novelty or originality, and task-appropriateness or meaningfulness, to which the socio-cultural and historical context has recently been added (Beghetto & Kaufman, 2008; Helfand et al., 2017; Kaufman et al., 2016; Plucker et al., 2018; Simonton, 2009). It is also highlighted lately that the discussions on creativity have focused on output and useful as well as practical outcomes that can be used or produced effectively to solve problems confronted in daily life (Cropley, 2020). In this sense, creative individuals have been referred to as the ones who come up with and "buy low" unique or promising ideas and after refining, "sell them high" (Lubart & Guignard, 2004, p. 45). Therefore, creative people have the ability to find alternative solutions to the problems they encounter that others cannot think of or visualize and to overcome obstacles that others may give up on (Kaufman 2016).

While the preceding explanations and perspectives highlight the complex and multidimensional nature of creativity, to further clarify the theoretical frames which underscore the sources and types of creative potential and behavior seem required. Sternberg and Lubart (1992) examine approaches to explaining creativity in two groups, person-centered and context-centered, with the former placing more emphasis on the internal or personal aspects of creative performance, while the latter focuses on the individual's interaction with the external environment. The investment theory that Sternberg and Lubart (1991) constructed also highlights similar notions and connotes that there are six sources of creativity: "intelligence, knowledge, intellectual styles, personality, motivation, and environment, the first five of which are related to person-centered, while the last is about context-centered" (Zhang & Sternberg, 2011).

While creativity is linked to individuals developing new and original ideas, person-centered approaches, in particular, emphasize the importance of the individual's trust in his or her creativity and feeling competent in creative processes (Beghetto & Karwowski, 2023; (Karwowski et al., 2019). Individuals' confidence in their creativity motivates them to overcome obstacles they encounter during the creative process and helps them express their ideas freely as their beliefs in evaluating and developing their own potential stand out as an important component of creative performance. Bandura (1997) argues that long-term and challenging creative processes require individuals to have persistent self-efficacy beliefs in themselves. Accordingly, in processes where progress is relatively stable and hopelessness about the results prevails, self-efficacy beliefs, namely, individuals' self-confidence in being able to produce original ideas, emerge as a concept that positively affects creativity (Supriatna, 2019).

Defined as "an individual's belief in one's capability to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3), the concept self-efficacy has its roots in social cognitive theory, and it is stated that as a self-regulatory mechanism, high levels of self-efficacy provide increased performance in many areas and various tasks (Gerhardt & Brown, 2005). Haase et al. (2018) assert that self-efficacy is a matter of how long and how much effort individuals put in to find a successful result or an effective solution. In this context, the point that needs to be underlined is the belief that individuals feel about themselves throughout the process, so self-efficacy emerges as an important concept in explaining and understanding the increase in performance in the field of creativity. It is stated that the concepts of creativity and self-efficacy are related to the perceptions of individuals about their abilities and skills in solving the problems they encounter and successfully developing alternative solutions. The combination of the two concepts provides the production of innovative ideas and the performance increase brought about by the personal belief emphasized by the concept of self-efficacy (Bandura, 1997; Valdez-Juárez & Pérez-De-Lema, 2023). Therefore, when individuals believe that they can accomplish assigned tasks and have confidence in themselves, they are more possibly to engage in the process and develop their ideas originally because they feel the potential for success (Valdez-Juárez & Pérez-De-Lema, 2023).

Schunk (1991) states that self-efficacy is not the only factor or the most important factor affecting behavior, but that expectations or beliefs about the outcome are important, as individuals' expectations or beliefs about negative outcomes will not motivate them. Research on motivation suggests that the notion of self-efficacy in Bandura's social cognitive theory is an important and fundamental part of academic motivation (Bryant, 2017), given that self-efficacy is theoretically linked to motivation and perseverance, or the ability to persist in action when faced with problems (Supriatna, 2019). In other words, the belief about oneself affects not only the individual's behavior but also his or her motivation for personal development and success. In this context, the relationship between self-efficacy and motivation gains a deeper meaning within the framework of Self-Determination Theory (SDT). Self-Determination Theory aims to understand the internal and external sources of motivation of the individual and is based on the three basic psychological needs of individuals:

autonomy, relatedness, and competence. While autonomy is related to having a feeling of autonomy when making choices, relatedness focuses on internal tendencies such as the need to establish relationships, the sense of belonging, caring, being loved and cared for. Competence, which is closely associated with self-efficacy, underscores the desire or tendency of individuals to feel effective and competent when interacting with the environment, which is supposed to strengthen their internal motivation and make them more enthusiastic to learn (Deci & Ryan, 2000; Margolis & McCabe, 2006; Petrich, 2020; Ryan and Deci, 2009; Van Den Broeck et al., Wentzel et al., 2016; 2021; Zheng et al., 2020). Being one of the theories that explains the motivation of individuals in the most effective and detailed way, SDT is presented as a construct in which motivation is grouped as "intrinsic and extrinsic", with the main point emphasizing what type of motivation an individual has rather than the amount or level of motivation (Deci & Ryan, 2000; Dörnyei, 2003; Pelletier, 2002; Ryan & Deci, 2009; Zheng et al., 2020). Bryant (2017) attests that both self-efficacy and motivation are motives that enable individuals to adopt and pursue a goal and to persevere in the face of challenges. Individuals with a relatively high sense of efficacy tend to take on more demanding tasks and are more persistent and motivated in the face of obstacles. Deci and Ryan (1985), citing White (1959), maintain the need for a basic motivational initiative that drives a wide range of non-impulsive behaviors and suggest that there is an intrinsic satisfaction in expanding one's capabilities, where the energy behind this activity is called motivation and the corresponding effect is named efficacy.

Self-efficacy, confidence or belief in one's ability, promotes motivation that enhances creative thinking and innovation. Related literature underscores the fact that higher levels of creative self-efficacy increase confidence associated with creativity and thus motivates individuals to have creative outcomes (Anggarwati & Eliyana, 2015; Bozdoğan, 2023; Chen et al., 2023; Tierney & Farmer, 2011). The findings of various studies in terms of the significance of self-efficacy perception and motivation are consistent with the theoretical framework. Among others, Chowdhury and Shahabuddin (2007), Taheri-Kharameh et al., (2018), Williams et al., (2014), Saracaloğlu and Dinçer (2009), and Yüner (2020) found a significant and positive relationship between self-efficacy and motivation. Specifically, as for the role of intrinsic motivation, Gan et al. (2023) found a positive and significant relationship between intrinsic motivation and English language self-efficacy. Similarly, the positive and significant relationship was also evidenced by Alci (2015), Atik (2020), Chen and Sukying (2024), Fatima et al. (2018), Rossi et al. (2020) and Walker et al.'s (2006) studies. Farmer and Tierney (2017) assert that self-efficacy and intrinsic motivation are diverse motives that promote the creativity levels of individuals. In this context, Zhou et al. (2012) in their research focusing on problem-solving demand and creativity found that intrinsic motivation acted as a moderator in the association and that the link was far more powerful for the ones with high levels of intrinsic motivation. The studies focusing on the relationship between extrinsic motivation and self-efficacy generally yield a negative linkage. For instance, the studies conducted by Walker et al. (2006), Rossi et al. (2020) as well as Martinelli and Sassi (2010), revealed a negative relationship between extrinsic motivation and self-efficacy, which could be attributed to the fact that extrinsic motivation focuses on external factors and occurs when an activity is performed to gain separable consequences. In contrast to intrinsic motivation, it does not provide joy or satisfaction in the activity itself but bears a kind of instrumental value and compliance (Gan et al., 2023; Ryan & Deci, 2000).

As a conclusion, the notion of self-efficacy increases individuals' beliefs in themselves and their ability to realize their potential. It is observed that individuals with high self-efficacy levels have a highly developed capacity to cope with the difficulties they face, and therefore the concept itself serves critical importance for individuals to realize themselves and produce creative solutions, because being related to individuals' beliefs about their ability to achieve any goal, self-efficacy is commonly acknowledged as a fundamental psychological construct that influences many aspects of performance, including creative solutions or products. Thus, exploring the relationship between creativity, which is an indispensable skill in social, professional and academic settings, and self-efficacy could yield deeper insights on how self-efficacy evolves into creative potential. In this sense, motivation emerges as an element that enables individuals to actively participate in the learning process and supports creativity and is therefore closely related to self-efficacy, because while motivation bridges the gap between one's performance and abilities, lack of motivation, on the other hand, leads to a decrease in individuals' self-belief and, as a natural consequence, to their failure to fully demonstrate their potential.

In this study, while the relationship between self-efficacy and creativity is examined, the reflections of intrinsic and extrinsic motivation factors as mediating factors on this relationship will also be explored, which will add further implications to the related literature. Intrinsic motivation, which is associated with personal interests, desires and tendencies, brings deeper engagement and more effective creativity processes to the forefront. On the other hand, extrinsic motivation, which is essentially related to external promises or rewards, can also activate and spur creative processes, although its reflections could vary depending on the

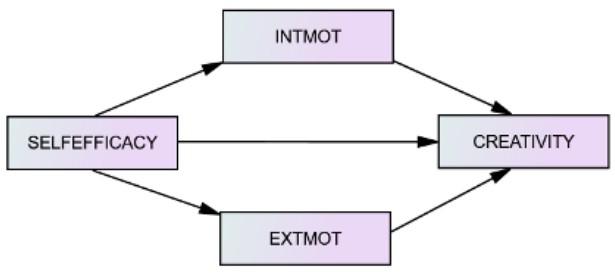
context and task nature. In this context, university students as a study group could provide important demographic reflections in that university setting is structured in a way that it enhances, among others, intellectual curiosity, skill development, critical thinking and creativity as they constantly handle problem-solving, producing innovative ideas, trying to find out and observe their beliefs and aptitudes and interacting with others. In addition, at this level, they are more prone to acknowledge their opinions about themselves and about what makes them stimulate to have creative outcomes.

The present research, addressing the relationship between self-efficacy and creativity and examining how intrinsic and extrinsic motivation mediates this relationship separately, is thought to contribute to understanding which type of motivation directs self-efficacy to creative behavior more effectively. The findings are thought to be useful for educators and practitioners who aim to promote innovative environments and processes and to reveal individuals' beliefs in success. In this vein, the present study intends to examine the impact of individuals' beliefs regarding their potential on creative endeavors and identify how intrinsic interests and pleasures, as well as external incentives and rewards, contribute to the pathway between self-efficacy and creativity. More specifically, the main purpose of this study is to examine the association between self-efficacy and creativity and particularly to focus on investigating the mediating roles of intrinsic and extrinsic motivation. With this aim, the research intends to provide detailed insights into the role of motivation in the context of self-efficacy and creativity and to contribute to the process of utilizing more effective approaches to enhancing creative endeavors in educational settings.

Research Questions:

1. How does self-efficacy relate to creativity?
2. To what extent does intrinsic motivation act as a mediator in the relationship between self-efficacy and creativity?
3. To what extent does extrinsic motivation act as a mediator in the relationship between self-efficacy and creativity?

Figure 1.
The model with intrinsic and extrinsic motivation as moderators



Methods

Research Design

The present study follows the quantitative approach to explore the relationship between self-efficacy and creativity through the mediating roles of intrinsic and extrinsic motivation. Mediation analysis is employed in order to examine the mediating roles through Structural Equation Modeling (SEM), a statistical method that consents the examining of a set of associations among one or more independent variables and one or more than one dependent variables (Ullman & Bentler, 2012). The application of SEM in the current study is due to its allowance for the analysis of the relationships of multiple variables including the estimation of direct and indirect effects among numerous variables (Valeri & VanderWeele, 2013). In the present study specifically, SEM allowed the examination of intricate links among self-efficacy, meta-cognitive awareness, reflective thinking, and critical thinking, within a single model as the latent variables.

Participants

The data collection tools were administered to a total of 197 participants attending a university in İstanbul at diverse departments chosen in line with the principles of convenient sampling (Creswell, 2012). The present study employed this type of sampling in that allowed to select participants based on their availability and eagerness to take part in the research. As the participants were attending preparatory classes, the opportunity for representing a diverse cross-section of various academic majors in the university. In the sample, there were 93 (47.2%) female participants and 104 (52.8%) male participants. The tools were administered to the participants in their classes in the academic year of 2023-2024, and the participants were informed about the confidentiality of the data and that the participation was entirely based on voluntariness. In table 1, the demographic variables of the participants are presented.

Table 1
The Demographic Characteristics of the Sample

		f	%
Gender	Female	93	47.2
	Male	104	52.8
Age	17-20	185	94
	21-23	9	5
	24-26	3	1
Total		197	100

Instruments

The Marmara Creative Thinking Dispositions Scale

The Marmara Creative Thinking Dispositions Scale consists of 25 items and six structures (innovation

search, courage, self-discipline, inquisitiveness, doubt, and flexibility). Being a five-Likert tool ranging from "Never" (1) to Always (5)", the scale was developed by Özgenel and Çetin (2017), and the reliability of the whole scale was found as Cronbach's alpha internal consistency coefficient .91. According to the results of the test-retest, the correlation coefficient was found to be significant for the whole scale (r =.88; p <.001).

The Academic Self-Efficacy Study

Developed by Owen and Froman (1988), The Academic Self-Efficacy Scale was adapted into Turkish culture by Ekici (2012). For validity and reliability, the scale was administered to 683 university students, and it was found to have three sub-dimensions ("social status, cognitive applications and technical skills"). Consisting of 33 items and prepared in the form of five-Likert scale, it ranges from "strongly disagree (1) to strongly agree (5). The reliability coefficient as Cronbach's alpha for the whole scale was found to be .86. Cronbach's alpha value was .88, .82 and .90 for "social status, cognitive applications and technical skills dimensions", respectively.

The Academic Motivation Scale

The Academic Motivation Scale was originally developed by Vallerand et al. (1992) and translated into Turkish by Karataş and Erden (2012). The scale consists of 27 items and three sub-scales, assessing three different types of motivation ("intrinsic motivation, extrinsic motivation and amotivation"). Prepared in a seven-Likert form ranging from "does not correspond at all (1) to corresponds exactly (7)", the internal consistency coefficient of the scale was found to be .97 Cronbach alpha and the factor analysis values also demonstrated that there were seven factors explaining 68.59% of the total variance in the scale (Karataş & Erden, 2012). In the present study, the items for intrinsic (10 items) and extrinsic motivation (13 items) were analyzed and Cronbach's alpha value in the study without the presence of amotivation subscale was found to be .83.

Data Analysis

Prior to data collection, the participants were appraised of the study's aim and were provided informed consent. Data collection tools were administered in the classrooms under the supervision of the lecturers. Responses gained through the tools were screened for completeness and invalid papers were excluded. The dataset was then inputted into software program (SPSS, 23.0) for the analysis.

The data obtained from the data collection tools were conducted to investigate the relationship between self-efficacy and creativity through the mediating roles of intrinsic and extrinsic motivation. First, descriptive statistics were obtained regarding the data, and Pearson correlation coefficients were calculated to evaluate the relationships between the variables. In the following process, whether intrinsic and extrinsic motivation had any role in the relationship between self-efficacy and creativity was tested through SEM. The aim of this analysis was to determine the direct or indirect effect of intrinsic and extrinsic motivation on the relationship in question.

Findings

The values of descriptive statistics along with skewness and kurtosis of the variables of the study are presented in Table 2.

Table 2
The Descriptive Values of the Variables

	N	*M*	*SD*	*SE*	Min.	Max.	Range	Skew-ness	Kurtosis
Creativity	197	80.56	24.60	1.74	52	115	63	-.584	-.112
Self-Efficacy	197	96.98	22.94	1.60	53	140	87	-.738	.293
Intrinsic Mot.	197	39.21	8.98	0.64	33	45	12	-.679	.336
Extrinsic Mot.	197	40.46	12.85	0.90	27	62	35	.103	.844

Table 2 presents the descriptive statistics of the variables involved in the study. The arithmetic means of creativity, self-efficacy, intrinsic motivation and extrinsic motivation were computed at 80.56 (*SD* = 24.60), 96.98 (*SD* = 22.94), 39.21 (*SD* = 8.98) and 40.46 (*SD* = 12.85), respectively. As illustrated, the skewness and kurtosis values of the variables are between +1 and -1; they suggest a normal distribution of the data (Hair et al., 2022).

The correlation values among creativity, self-efficacy, intrinsic and extrinsic motivation are illustrated in Table 3.

Table 3
The Correlation Analysis

	1	2	3	4
Creativity	1			
Self-Efficacy	.394*	1		
Intrinsic Mot.	.502*	.641*	1	
Extrinsic Mot.	.061	.331*	.405*	1

*p < 0.01 (two-tailed)

As illustrated in Table 3, the correlation values between self-efficacy and creativity (r = .394; p < 0.01); intrinsic motivation and creativity (r = .502; p < 0.01); intrinsic motivation and self-efficacy (r = .641, p < 0.01); extrinsic motivation and self-efficacy (r = .331, p < 0.01) and extrinsic motivation and intrinsic motivation (r = 405, p < 0.01) were statistically significant and positive. On

the other hand, although the association between extrinsic motivation and creativity (r = 0.61, p > 0.05) was positive, it was not statistically significant.

Figure 2 shows the unstandardized regression values of the model with the mediating roles of intrinsic and extrinsic motivation.

Figure 2.
The regression values of the model

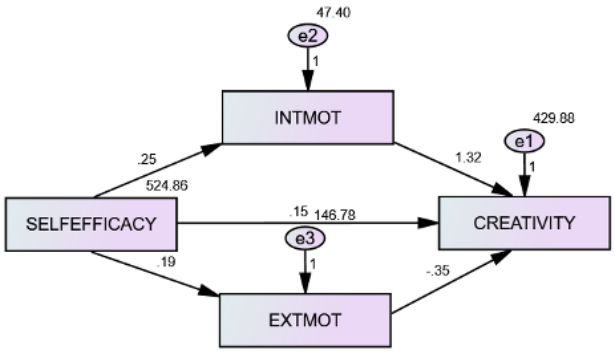


Table 4 presents the regression weights, standard errors, critical ratios, and p-values of the variables.

Table 4 illustrates that the predictive power of self-efficacy on creativity (MLE = .15; CR = 2.39), self-efficacy on intrinsic motivation (MLE = .25; CR = 15.74), intrinsic motivation over creativity (MLE = 1.32; CR = 8.27), self-efficacy over extrinsic motivation (MLE = .18; CR = 6.59) are statistically significant and positive. On the other hand, the predictive pattern between extrinsic motivation and creativity is statistically significant though negative.

Table 5 illustrates the association between self-efficacy and the mediating roles of intrinsic and extrinsic motivation.

Table 5 summarizes the mediating roles of intrinsic and extrinsic motivation on the relationship between self-efficacy and creativity. The findings disclosed statistically a positive and significant indirect effect of intrinsic motivation on the relationship between self-efficacy and creativity (b = 0.155, t = 0.664, p < 0.01). Similarly, the direct effect of self-efficacy without the mediating role of intrinsic motivation was also positive and significant (b = 0.330, p < 0.01). On the other hand, upon analysing the effect of extrinsic motivation on the linkage between self-efficacy and creativity, the findings revealed a significant but negative mediating role of extrinsic motivation (b = -0.064, t = -2.096, p < 0.05). As illustrated, the lower and upper bound values for the relationship with the presence of intrinsic motivation range from 0.243 to 0.444, while with the mediating role of extrinsic motivation, the values lie between -0.136 and -0.014 at the 95% confidence interval. Thus, it can be concluded that intrinsic and extrinsic motivation partially mediated the association between self-efficacy and creativity.

Discussion

The current study centres on the association between self-efficacy and creativity with the presence of intrinsic and extrinsic motivation as moderators. Upon analysing the data, the findings revealed a significant and positive association between self-efficacy and creativity, indicating that individuals' self-beliefs and their confidence affect their creativity levels in a positive way. Further, the findings also underscored that intrinsic motivation as a mediator over the relationship between self-efficacy and creativity acts in a positive and significant way, which underlines the significant role of intrinsic motivation as an important variable in increasing the creativity levels of university students.

This is especially pertinent for university students in that they usually confront settings and conditions that entail creative endeavours, innovation, practical solutions for the problems that they encounter and self-beliefs as well as confidence of themselves.

Table 4
The standardized values of regression weights, standard errors, critical ratios, and p

	MLE	SE	CR	*p*
SE → CRT	.14	.06	2.39	.00**
SE → INT	.64	.01	15.74	.00**
INT → CRT	.47	.16	8.27	.00**
SE → EXT	.33	.02	6.59	.00**
EXT → CRT	-.18	.09	-3.85	.017*

**p < 0.01; *p < 0.05; SE = Self-Efficacy; CRT = Creativity; INT = Intrinsic Motivation; EXT = Extrinsic Motivation

Table 5
The Mediation Analysis

Relationship	Direct Effect	Indirect Effect	Confidence Interval		p-value	Conclusion
			Lower Bound	Upper Bound		
SE → INT → CR	0.330	0.155	0.243	0.444	0.00**	Partial Mediation
SE → EXT → CR	(0.000)	-0.064	-0.136	-0.014	0.013*	Partial Mediation

**p<0.01; *p < 0.05, SE=Self-Efficacy; CRT=Creativity; INT=Intrinsic Motivation; EXT=Extrinsic Motivation

Hence, with high levels of self-efficacy beliefs as well as elevated inner drive, they would be able to take on more creative acts such as projects, academic tasks and research. In this context, in educational settings, the learning practices that underscore motivation, self-confidence, autonomy as well as reflective practices should be prioritized.

When the role of extrinsic motivation in the relationship is examined, it can be stated that the variable acts as a significant but negative mediator over the linkage between self-efficacy and creativity. When compared to intrinsic motivation, it is observed that extrinsic motivation has a rather restrictive and negative effect on the creativity levels of individuals. Therefore, the findings show that the mediating effect of intrinsic motivation is significant and positive, and it serves as a strong and supportive component in the relationship between self-efficacy and creativity, unlike extrinsic motivation, which, according to the findings, acts as a weakening mediator.

As a response to the first research question of the study, the findings underscore that individuals' self-beliefs and confidence in themselves positively affect their creativity incentives. The positive relationship between self-efficacy, defined as individuals' belief in their abilities and skills to solve the problems they confront or the tasks assigned to them (Bandura, 1997), and creativity, illustrated as the ability to produce innovative, unique and original ideas (Stenberg, 1985), reveals that individuals with high self-efficacy are more effective in creative processes and can produce original ideas. Farmer and Tierney (2017) suggest that in creative processes, especially when faced with discouraging and demotivating difficulties such as frequent failures at the starting point, individuals need a driving force that will mobilize their determination and perseverance in order to take creative action at this point. In this sense, self-efficacy provides such power in terms of choice, initiation, participation and sustainability. Thus, upon confiding in themselves and their potential, individuals could be more daring and enthusiastic when confronted with challenges and restrictive boundaries while coming up with creative ideas, which helps them utilize their creativity more efficiently and competently. Then, due to the difficulties inherent in the creativity process, perseverance and resilience are necessary for individuals to realize their creative potential (Coursey et al., 2018), as, after all, self-efficacy beliefs not only provide information about, but can also be predictive of, whether people who have the tendency and ability to perform creatively will engage in a task they encounter, whether they will make an effort to accomplish the task, and ultimately whether they will carry out the creativity process as required (Beghetto & Karwowski, 2023). Several studies in the related literature seem to support the highlighted association between self-efficacy and creativity. For instance, a meta-analysis conducted by Haase et al. (2018) with 17226 participants involved revealed a strong relationship between self-efficacy and creativity (r=.53). Similarly, in another meta-analysis with a sample size of 11621, Herianto (2024) found the relationship between self-efficacy and mathematical creativity positive and significant.

As a response to the second research question of the study, the role of intrinsic motivation was examined, and the findings revealed that as a moderator, intrinsic motivation acts in a positive and significant way on the link between self-efficacy and creativity. Amabile (2013), in her widely cited theory of the componential model of creativity, argues the essential components that lead to creativity, one of which is intrinsic motivation, being a central tenet. The theory asserts that "people will be most creative when they feel motivated primarily by the interest, enjoyment, satisfaction, and challenge of the work itself – and not by external pressures" (Amabile & Fisher, 2009, p. 2). In line with the theory, numerous studies have examined the link between intrinsic motivation and creativity. Among others, Fischer et al. (2019), Cromwell et al. (2023), and Choi (2004) found a positive and significant relationship between the constructs. In addition, a meta-analysis conducted by De Jesus et al. (2013) with 6435 participants also revealed a positive and significant relationship. These findings highlight the creative processes that intrinsic motivation helps promote and emphasize that when the individuals have an intrinsic interest in the activities they perform and enjoy them, their creativity levels become far more evident. Reviewing the obtained findings and relevant literature reveals that individuals' self-efficacy perceptions support the emergence of original and unique ideas through creativity processes. At this point, it can be stated that individuals with high self-efficacy perceptions increase their creativity levels with their beliefs about themselves and high-level intrinsic motivation. In other words, as observed in this study, individuals' beliefs about themselves supported by intrinsic motivation help increase creativity performance.

The findings obtained from the study have revealed that extrinsic motivation plays a negative mediating role in the relationship between self-efficacy and creativity. This shows that extrinsic motivation may have a limiting and reducing effect rather than encouraging creativity levels. Extrinsic motivation focuses on external factors and occurs when an activity is performed to gain separable consequences. In contrast to intrinsic motivation, it does not provide joy or satisfaction in the activity itself but bears a kind of instrumental value and compliance (Gan et al., 2023; Ryan & Deci, 2000). Individuals possessing or tending to have this type of motivation may direct them to traditional or risk-free solutions. This situation

may inhibit their independent and free thinking in creative processes and limit their potential to produce new ideas. The finding of the current study is consistent with some studies suggesting the negative or no association between extrinsic motivation and creativity. For example, the studies of Cooper and Jayatilaka (2006), Baer et al. (2003), Prabhu et al. (2008), and Zhu et al. (2018), along with Amabile (1985) demonstrated that extrinsic motivation has a kind of lowering effect or negative relationship with creativity. This may connote the idea that when factors such as external reward, fear of disapproval, punishment, and fear of being evaluated in a negative way by others are involved, individuals may focus on meeting expectations rather than thinking creatively. Therefore, the negative mediating role of extrinsic motivation on creativity may limit the ability of individuals to think independently and uniquely in their creative processes. In addition, the confidence interval of extrinsic motivation (–0.136 and –0.014) gained through the data, unlike that of intrinsic motivation (0.243 and 0.444) also suggests that intrinsic motivation could be an important motive for creativity, whereas extrinsic motivation could serve as a restrictive factor.

Conclusion

To sum up, the findings of the current study confirm that there is a significant and positive relationship between self-efficacy and creativity, and that intrinsic motivation has an important mediating role supporting this relationship. On the other hand, it is seen that extrinsic motivation has a limiting or weakening effect on the relationship. The findings underscore the significance of promoting self-belief and inner-drive in educational settings. In this context, the study offers key insights for university students who are supposed to have these skills for their academic and prospective careers. This indicates that when the students have internal motivation out of curiosity or interest, and with the help of high self-efficacy beliefs, then they are far more inclined to reach creative outcomes. Therefore, in processes that require creativity, individuals' joy in what they do and acts in line with their own desires and motives help them to come up with original and new ideas, which are the basic elements of creativity. On the other hand, individuals' actions when based on expectations prevent original ideas from being put forward and limit creative performance.

Implications

This research provides evidence that self-efficacy has a significant relationship with creativity processes and that intrinsic motivation plays an important mediating role in supporting individuals to perform better in creative processes. It is recommended that structures that support the intrinsic motivation of individuals be established, especially in educational settings where creativity is desired to be encouraged. Opportunities such as providing opportunities that consider the interests of individuals and allowing them to think and act freely can help to reveal more creativity. In addition, it should be kept in mind that extrinsic motivation practices based on external motivations may have relatively limiting characteristics on creativity.

A thought-provoking follow-up study to the present research would be to examine the effect of intrinsic and extrinsic motivation on creativity in different cultural backgrounds. This could have important impacts over creativity and motivational factors could be an inviting field to study in this sense. In addition, exploring the impact of self-efficacy over creative performance perceptions at different age groups and in different fields could also be helpful.

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Determinant Factors of Scientific Literacy in Elementary School Science Learning

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Abstract

Science literacy is becoming an essential skill for students in the modern era to understand and participate in scientific and technological developments. This study explores the factors determining students' science literacy in learning Science in Elementary School. The research method used a quantitative method with an ex post facto approach. The population of this study was elementary school students in Jakarta, Indonesia, with a cluster random sampling technique helpful in determining a sample of 513 students. Data collection used a questionnaire instrument to obtain data related to the variables in this study. Data analysis used a structural equation model (SEM) with the help of the SMART-PLS 3.0 application program. The results explained that the significance value obtained was 0.000 (<0.05), indicating that students' science literacy skills have been positively and significantly influenced by various factors, both internal factors, including motivation, interest, and self-efficacy, as well as external factors including classroom climate, learning quality, and parental support. Likewise, understanding the factors that positively influence scientific literacy can equip teachers to approach science instruction more comprehensively and effectively, helping students enhance their conceptual understanding. By paying attention to these factors, teachers can also design learning models that are more conducive and supportive towards students' needs, thus providing the solution to improve science literacy at the elementary school level.

Keywords:

Internal Factors, External Factors, Science Learning, Science Literacy

Introduction

Scientific literacy, which is a vital skill for people in this era (Koyuncu et al., 2021), is also extremely important for pupils in the 21st century. This is consistent with the main goal of the Independent Curriculum applied in Indonesia, which is to enhance scientific literacy. The introduction of the Independent Curriculum was primarily motivated by Indonesia's underperformance in the 2012 Program for International Student Assessment (PISA). Scientific literacy refers to the capacity to apply scientific information in practical situations to address science-related challenges and enhance the overall standard of living. Nevertheless,

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there is a need for improvement in the scientific literacy skills of students in Indonesia (Aksu et al., 2023). Indonesia obtained a mean score of 403 on the PISA (Program for International Student Assessment) evaluation, whereas the average score for the OECD (Organization for Economic Co-operation and Development) was 493. Indonesia ranks 62nd out of 72 participants.

The scientific literacy abilities of students remain relatively low, as evidenced by the fact that all categories are below 50% (Aiman et al., 2020). The analysis of scientific literacy skills reveals that the identification of scientific problems scored only 19.69% in the poor category. The explanation of scientific phenomena scored 32.19% in the medium category, while the interpretation of data and evidence scientifically scored 33.59%, also falling within the medium category (Hanifha et al., 2023). Moreover, according to Sholikah and Pertiwi (2021), the overall scientific literacy proficiency of pupils is classified as moderate. However, one specific feature, namely the capacity to identify scientific issues, falls into the low category, with a percentage of 37.5%.

The study conducted by (El Islami & Nuangchalerm, 2020) revealed that both educators and students still need to enhance their scientific literacy skills. Furthermore, Haryadi and Pujiastuti, (2020) discovered that pupils possess a deficient level of scientific literacy. Therefore, it is imperative to provide educational instruction to enhance students' scientific literacy. The development of students' strong scientific literacy skills is crucial for effectively addressing everyday challenges and comprehending scientific concepts within their immediate surroundings. The lack of proficiency in scientific literacy among students in Indonesia indicates their inability to effectively solve problems. Indonesia's inability to compete at the international level is implied (Rusmansyah et al., 2023).

Natural Science learning in elementary schools is central to forming a solid foundation of scientific literacy in children. This is because science teaches scientific concepts and develops essential science process skills (Hastuti et al., 2020). Students learn through science to observe, classify, create hypotheses, and conduct experiments, helping them understand how science works in practice (Pramudiyanti et al., 2023; Zulherman et al., 2021). The foundations embedded in science learning prepare students to understand the world around them and equip them with the tools and understanding necessary to face future scientific challenges. Science learning in elementary school not only enriches students' knowledge but also forms a solid foundation for their scientific literacy in the future. Scientific literacy depends not only on understanding scientific concepts but also on mastering fundamental scientific process skills (Perdana Putra et al., 2021; Rorimpandey et al., 2022). Observation, classification, hypothesis generation, and conducting experiments are critical to adequate scientific literacy. However, behind the success of scientific literacy, various determinant factors influence the learning process and student achievement.

Factors that have received significant attention from educators and researchers are the role of the learning environment, the quality of the learning process, the level of motivation, demonstrated interest, and the level of self-efficacy, both in the school environment and outside of school (Darling-Hammond & Cook-Harvey, 2018; Syofyan & Ratih, 2022). These factors play a crucial role in determining students' scientific literacy as they interact and mutually affect each other during the learning process (Abu Bakar et al., 2023). Learning environments that promote investigation, discussion, and practical application in a scientific context can greatly enhance the development of scientific literacy. In addition to the teacher's instructional quality, the amount of student motivation, interest in the learning content, and belief in one's abilities (self-efficacy) are also crucial factors in developing a strong foundation of scientific literacy in pupils (Keller et al., 2017a; Tuan et al., 2005).

Previous studies (Almeida et al., 2023; Tas et al., 2019; van Rooij et al., 2017) highlight that the determinants of scientific literacy still require improvement. Although efforts have been made to understand the factors influencing students' scientific literacy, there is still room for improvement. These findings indicate that certain aspects still need to be fully understood or handled effectively in science learning. Based on researchers' knowledge, research on the determinants of scientific literacy has been carried out comprehensively involving internal and external factors. However, most research tends to focus on high school students. Although this research provides valuable insight into the factors that influence scientific literacy in certain age groups, it needs to be acknowledged that science learning begins well before the high school level.

Elementary school is a critical phase in forming students' educational foundations, including the formation of scientific literacy. Therefore, it is essential to complement research on the determinants of scientific literacy with research that focuses more on elementary school students (Ni'mah, 2019; Shaffer et al., 2019). Teachers can design more effective and inclusive learning strategies by understanding the various determinant factors that influence scientific literacy in science learning in elementary schools (Hughes, & Braun, 2019). An integrated, empirically grounded strategy can facilitate the establishment of a learning setting that fosters the growth of students' scientific abilities, enabling them to confront forthcoming difficulties with assurance and proficiency (Fortus et al., 2022).

Scientific literacy in natural science learning at school is influenced by internal and external factors (Appleton, 2007). Internal student characteristics, including as motivation, curiosity, and self-efficacy, are crucial in influencing the level of student engagement and achievement in comprehending scientific topics. On the other hand, external factors, such as classroom climate, learning quality, and parental support, also play a crucial role in forming a learning environment conducive to developing students' scientific literacy (Bennett, 2010; Harlen, 2003).

The objective of this research is to identify and examine the factors that determine scientific literacy in primary school science education. By gaining a more profound comprehension of these factors, it is anticipated that the study can offer valuable perspectives for policymakers, educators, and educational practitioners to enhance the efficacy of science education at the elementary level. By bolstering our understanding of how factors such as student motivation, quality of education, and parental support impact scientific literacy, we can devise more efficient and inclusive learning approaches to enable every student to achieve their utmost potential in science education. Here are the research questions:

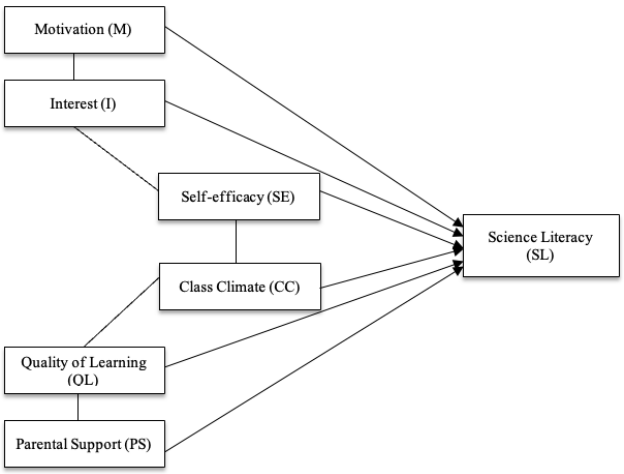
1. Do internal factors such as students' motivation, interest, and self-efficacy positively and significantly influence scientific literacy?
2. Do external factors such as classroom climate, learning quality, and parental support positively and significantly influence scientific literacy?
3. Can internal and external factors influence scientific literacy at the elementary school level?

Methods

Research design

This research uses quantitative methods with an ex post facto approach to analyze variables that can predict specific results (Al-Emran et al., 2019; Teo, 2014). This method allows researchers to collect data on existing variables and then analyze the influence of these variables (Balnaves & Caputi, 2018; Salkind, 2010). The conceptual model of this research is to examine the impact of internal factors (motivation, interest, and self-efficacy) and external (classroom climate, quality of learning, and parental support) on scientific literacy abilities in science learning. The research focuses on understanding how certain factors, both internal and external to students (exogenous variables), influence scientific literacy (endogenous variables). The variables analyzed include internal factors such as motivation, interest, and self-efficacy, as well as external factors such as classroom climate, learning quality, and parental support. By analyzing the influence of these factors, this study aims to provide a deeper understanding of how students' scientific literacy can be effectively improved through appropriate interventions at the primary education level. The research path model can be seen in Figure 1 below.

Figure 1.
Research Path Model



Population and Sampling Techniques

The population in this study consisted of elementary school students in the Jakarta area, Indonesia. From this population, a sample of 513 students was obtained, selected representatively using the cluster random sampling method. This technique involves selecting classes randomly from a number of elementary schools included in the study area. All students in the selected classes were then used as sample members. The data collection process was carried out using an instrument in the form of a questionnaire, which was distributed to students from the specified classes. The selection of elementary school students as research subjects was based on the need to identify and analyze factors that influence their scientific literacy skills. Further information regarding the details of the population and sample can be seen in the following table:

Table 1.
Total Population and Sample of Elementary School Students

School	Gender		N
	Male	Female	
SDN Wijaya Kusuma 02 Pagi	38	89	127
SDN Tanjung Duren Selatan 01 Pagi	61	71	132
SDN Jatipulo 05 Pagi	69	57	126
SDN Tamansari 03 Pagi	63	69	128
SDN Mangga Besar 15 Pagi	54	75	129
Total	285	361	513

*) SDN (term State Elementary School).

Research data collection

This research collects data regarding the determinants of scientific literacy in science learning in elementary schools. The instrument used was a five-point Likert scale questionnaire adopted from previous research. The process of developing this questionnaire refers to each variable in this research: motivation, interest and self-efficacy, classroom climate, quality of learning, and parental support and scientific literacy.

The questionnaire indicators for this research variable consist of 12 statements designed to be easily understood by elementary school students. Each statement uses language and information adapted to the level of understanding and age of children in grades 4, 5, and 6 so that they can answer questions more precisely and accurately. The indicators for each variable are: 1) Motivation: Hard work, task orientation, perseverance, and time use (Syofyan & Ratih, 2022). 2) Interest: feelings of enjoyment, student interest, and student involvement (Tarwiyani et al., 2020). 3) Self-efficacy: curiosity, resilience, learning patience, and learning motivation (Ferrell & Barbera, 2015). 4) Class climate: learning discipline, student involvement, student learning environment conditions, and positive student relationships with teachers (Darling-Hammond & Cook-Harvey, 2018). 5) Quality of learning: enthusiasm in receiving lessons, concentration in learning, activeness in asking and answering teacher questions, and ability to argue (Saleh, 2021). 6) Parental support: moral, material, and appreciation support (Booth et al., 2020). 7) Scientific literacy: identifying scientific questions, explaining phenomena scientifically and using scientific evidence (Masfuah et al., 2021).

The validity of this instrument is based on Piaget's theory, which shows that the cognitive abilities of children in grades 4, 5, and 6 have developed well, and they have sufficient reasoning abilities to understand the information presented in this instrument. Validity and reliability tests were carried out to ensure the validity and reliability of the data. The Likert Scale model questionnaire instrument has been carefully prepared to provide its relationship to scientific literacy skills in science learning. This process involves a review of theory and related literature to ensure that the items in the scale reflect the construct being measured. Reliability is also checked to ensure that the scale provides consistent results when repeated; it can be calculated using Cronbach's Alpha or test-retest. Each question in the research instrument uses a Likert scale with five alternative answers, where respondents can indicate their level of agreement with the statement asked. This Likert scale consists of five answer choices: "strongly agree" with a value of 5, "agree" with a value of 4, "somewhat agree" with a value of 3, "disagree" with a value of 2, and "strongly disagree" with a value of 1.

Research data analysis techniques

Data analysis in this research uses the Partial Least Square (PLS) method from Structural Equation Models (SEM) to analyze the relationship between variable construction, both exogenous and endogenous variables, as well as considering measurement error. The data analysis process is supported by SmartPLS 3.0 software, which is used to test research hypotheses (Memon et al., 2021). PLS-SEM is a model used to analyze the relationship between variables by paying attention to latent variables (constructs) and indicators. PLS-SEM produces path parameter estimates that maximize endogenous variables that exogenous variables can explain through structural models. The outer model (measurement model) in PLS-SEM analysis aims to measure the construct (latent variable) represented by the measurable indicators (Sarstedt & Cheah, 2019). By using this approach, this research can gain a deeper understanding of the relationships between variables in the context studied by considering aspects of accurate measurement.

The outer model is used to test the validity and reliability of the questionnaire indicators in this research and to measure the constructs appropriately. In testing the outer model, the criteria used include loading factor parameters with a value of more than 0.7 and Average Variance Extract (AVE) greater than 0.5. The loading factor and AVE parameters are the factors evaluated in these criteria. Furthermore, in hypothesis testing, the criterion used is the p-value. If the p-value is less than 0.05, the hypothesis is accepted, whereas if the p-value is more than 0.05, the theory is rejected. This hypothesis testing is carried out in the context of an inner model, where the relationships between variables are analyzed in more depth.

Results

Validity and reliability results

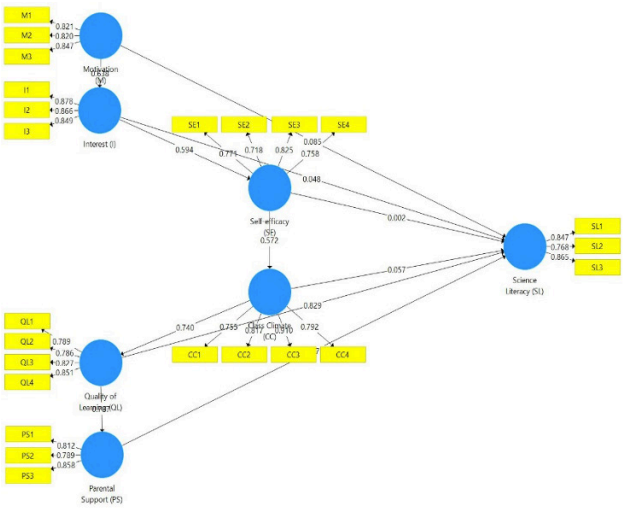
Analysis of validity and reliability tests on the questionnaire for each variable aims to ensure the reliability and validity of the research data. The analysis results show that the calculations that have been carried out meet validity standards (convergent and discriminant) and reliability standards. The factor loading values in this study used Confirmatory Factor Analysis (CFA), which was obtained from Cronbach's alpha, CR and AVE values as needed, as well as the outer model loading value for each factor in the latent variable was more than 0.7. The results of the validity and reliability tests can be seen in Table 2 below.

Table 2.
Results of validity and reliability test analysis of research variables

Variable	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Class Climate (CC)	0.837	0.891	0.673
Interest (I)	0.831	0.899	0.747
Motivation (M)	0.726	0.911	0.688
Parental Support (PS)	0.901	0.860	0.672
Quality of Learning (QL)	0.824	0.877	0.591
Science Literacy (SL)	0.871	0.867	0.685
Self-efficacy (SE)	0.913	0.892	0.591

The analysis results from Table 2 show that the Composite Reliability (CR) value for each variable construction ranges from 0.860 to 0.911, while the Cronbach's Alpha value ranges from 0.726 to 0.913. These figures show that the CR and Cronbach's Alpha values are satisfactory and acceptable, indicating high reliability and strong internal consistency for all formative constructs (Heale & Twycross, 2015). The QL5 indicator must be removed because it has an outer loading of less than 0.6. Composite Reliability (CR) exceeding 0.7 (Bajpai & Bajpai, 2014)indicates that all constructs in the model are reliable, answering the research question about overall construct reliability. The recapitulation results of this research's construction pathway model can be seen in Figure 2 below.

Figure 2.
Significant path coefficient from PLS Algorithm results



This research uses the path coefficient test to analyze the hypothesis. However, before proceeding to the hypothesis testing stage, it is necessary to analyze the fit model of the research data using the goodness of fit test. The results of the normed fit index (NFI) and standardized root mean square residual (SRMR) values are used as a category for whether the model is fit or not. This model fit test is assisted using the SMARTPLS-SEM program. The model is fit if the NFI value exceeds 0.8 and the SRMR is below 0.10. The results of this research's fit model show that the NFI value is 0.814 and the SRMR value is 0.092, so the model of the research variables is declared fit (Hair et al., 2021). Research hypothesis data were analyzed using the bootstrapping test method in SMARTPLS 3.0. This method aims to test hypotheses or obtain estimates of population parameters based on existing samples and test the significance value of each selected hypothesis. The results of the hypothesis analysis using the bootstrapping test method can be seen in Table 3 below.

Table 3.
HTMT Value

Variable	CC	I	M	PS	QL	SL	SE
Class Climate (CC)	0.820						
Interest (I)	0.624	0.864					
Motivation (M)	0.695	0.638	0.830				
Parental Support (PS)	0.693	0.616	0.631	0.820			
Quality of Learning (QL)	0.740	0.703	0.705	0.787	0.814		
Science Literacy (SL)	0.711	0.677	0.695	0.705	0.910	0.828	
Self-efficacy (SE)	0.572	0.594	0.526	0.530	0.631	0.593	0.769

Notes: CC (Class Climate); I (Interest); M (Motivation); PS (Parental Support); QL (Quality of Learning); SL (Science Literacy); SE (Self-efficacy).

Table 4.
Results of hypothesis analysis via SEM

Variable	Original Sample (O)	T-Statistics	P-Values
Class Climate (CC) -> Parental Support (PS)	0.582	18.439	0.000
Class Climate (CC) -> Quality of Learning (QL)	0.740	27.238	0.000
Class Climate (CC) -> Science Literacy (SL)	0.629	15.356	0.000
Interest (I) -> Class Climate (CC)	0.340	9.585	0.000
Interest (I) -> Parental Support (PS)	0.198	7.219	0.000
Interest (I) -> Quality of Learning (QL)	0.251	8.122	0.000
Interest (I) -> Science Literacy (SL)	0.262	5.879	0.000
Interest (I) -> Self-efficacy (SE)	0.594	15.315	0.000
Motivation (M) -> Class Climate (CC)	0.217	7.247	0.000
Motivation (M) -> Interest (I)	0.638	17.922	0.000
Motivation (M) -> Parental Support (PS)	0.126	5.798	0.000
Motivation (M) -> Quality of Learning (QL)	0.160	6.355	0.000
Motivation (M) -> Science Literacy (SL)	0.252	6.163	0.000
Motivation (M) -> Self-efficacy (SE)	0.379	9.567	0.000
Parental Support (PS) -> Science Literacy (SL)	-0.071	1.714	0.087
Quality of Learning (QL) -> Parental Support (PS)	0.787	34.296	0.000
Quality of Learning (QL) -> Science Literacy (SL)	0.773	18.725	0.000
Self-efficacy (SE) -> Class Climate (CC)	0.572	17.096	0.000
Self-efficacy (SE) -> Parental Support (PS)	0.333	10.783	0.000
Self-efficacy (SE) -> Quality of Learning (QL)	0.423	12.721	0.000
Self-efficacy (SE) -> Science Literacy (SL)	0.361	9.211	0.000

The analysis results from Table 3 explain that the HTMT (heterotrait-monotrait ratio of correlations) value is used to measure discriminant validity. As shown in Table 3, the HTMT value must be < 0.85 (Leguina, 2015) to demonstrate adequate discriminant validity. The results of the HTMT values show that all values are below 0.85, which confirms that there are no problems related to discriminant validity (Hidayat & Patricia Wulandari, 2022). Thus, hypothesis analysis using SEM can be continued to analyze the determinants of scientific literacy in science learning in elementary school.

The analysis results in Table 4 explain that each variable can have a direct influence. Exogenous variables, which include internal factors (motivation, interest, and self-efficacy) and external factors (classroom climate, learning quality, and parental support), significantly influence the endogenous variable, namely students' scientific literacy. The *p*-value of 0.000 <0.05 indicates that internal and external factors positively affect students' scientific literacy. However, parental support as an external factor is not included in the variables that have a positive influence because the *p*-value is 0.087 > 0.05.

The R-Square coefficient value of the exogenous variable against the endogenous variable is 0.507, which indicates that 50.7% of the variation in students' scientific literacy abilities can be explained by the internal and external factors used in this research. This increase occurred because factors such as motivation, interest, self-efficacy, classroom climate, quality of learning, and parental support influenced students' enthusiasm for learning science in elementary schools. The hypothesis in this research can be accepted, which confirms that students' scientific literacy abilities can be influenced by various factors, as explained in this research.

Discussion

Scientific literacy is essential and must be instilled in Indonesian students from an early age (Huang et al., 2022; Krajcik & Czerniak, 2018). This is important considering competition in technology and knowledge in the 21st century, which demands the ability of individuals to compete and follow global trends (Bahtiar et al., 2022; Widodo et al., 2020). The focus on science learning as a collection of knowledge aims to enable students to demonstrate, discuss, or ask questions that enable them to remember interrelated facts, events, concepts, principles, laws, and theories (Heliawati et al., 2022; Sun & Chan, 2024). This concept also aligns with research by Kähler et al., (2020), which shows that effective learning occurs when what is learned in class can be applied in everyday life through scientific literacy.

Scientific literacy refers to a person's ability to participate in solving science-related problems and interact with scientific ideas, which in turn forms an individual who is critical and reflective of scientific issues (Kutlu-Abu et al., 2024). A person is considered "literate" in science when he can engage in various aspects of science and technology, demonstrate competence to formulate scientific explanations of phenomena, evaluate information, design scientific research, and interpret and present scientific data and evidence effectively (Nurcahyani et al., 2021; Winarni et al., 2020). Scientific literacy is not only about understanding scientific concepts but also about applying critical and analytical thinking in the context of science, which is crucial to forming a society that thinks scientifically (Adriyawati et al., 2020).

Scientific literacy abilities in natural science learning at school are greatly influenced by internal and external factors for students (Wahyu et al., 2020). Internal factors, including motivation, interest, and self-efficacy, have strongly influenced students' scientific literacy. These three aspects are interrelated in an essential way in encouraging students in the learning process. Motivation provides the drive and energy needed to face learning challenges, while interest enriches the learning experience by generating a deep curiosity about science topics. Furthermore, self-efficacy, or belief in one's abilities, plays a crucial role in determining the extent to which students are engaged and successful in understanding science concepts (Aristeidou & Herodotou, 2020; Wen et al., 2020). With high motivation, interest and self-efficacy, students tend to be more motivated to learn, more active in seeking knowledge, and more confident in dealing with complex science material. Therefore, developing these internal factors is essential in increasing students' scientific literacy (Ke et al., 2021; Queiruga-Dios et al., 2020).

External factors, including classroom climate, learning quality, and parental support, significantly and positively impact students' scientific literacy. These three elements work in synergy to encourage students to become more energetic and active in participating in science learning (Chen et al., 2021). A positive and supportive classroom climate creates a fun and safe learning environment for students to feel comfortable expressing opinions and interacting with teachers and classmates (Saraswati et al., 2021; Suwono et al., 2022). The high quality of learning, with innovative teaching methods and relevant materials, also helps increase students' interest in science and encourages them to be more enthusiastic about learning (Atta et al., 2020; Rosana et al., 2020).

Although the research analysis results show that the variable parental support does not have a significant favourable influence on students' scientific literacy,

it is essential to recognize that parental support remains a significant external factor in forming a supportive learning environment (Pujawan et al., 2022). The support and encouragement provided by parents give students additional confidence and deep motivation to explore science further outside the school environment (Nida et al., 2020; Sholahuddin et al., 2023). The direct impact of the parental support variable may not be significant. However, the role of parents in providing moral support, motivation, and practical assistance in science learning should be addressed (Ayu et al., 2021; S.-Y. Huang et al., 2020). This support not only helps students face challenges and difficulties in learning but also forms a positive attitude towards learning and strengthens students' intrinsic motivation (Jampel et al., 2018).

Previous research (Bryan et al., 2011; P.-S. Huang et al., 2020; Lo et al., 2021) highlights the complexity of the determinants of students' scientific literacy abilities in the context of science learning. Various variables can influence students' scientific literacy, both internal and external, each with different aspects. Internal factors, such as motivation, interest, and self-efficacy, play a key role in determining how well students can master science concepts. Motivation encourages learning, interest enriches the learning experience with deep curiosity, and self-efficacy provides confidence in the student's success (Lestari & Rahmawati, 2020).

External factors also have a significant impact. Parental support and involvement, for example, can provide moral and practical encouragement to students and create an environment that supports learning at home (Keller et al., 2017b; Van Vo & Csapó, 2022). A positive classroom climate and high-quality learning can also influence students' motivation and interest in science. This research confirms that no single factor can fully explain students' scientific literacy. Instead, the interaction between these various internal and external factors provides a more complete picture of how students develop their scientific literacy skills (Darling-Hammond et al., 2020; Kutsyuruba et al., 2015). Educators can better understand these complexities and design more effective and sustainable learning strategies considering all aspects influencing students' scientific literacy abilities (Asano et al., 2021; Christina Ismaniati & Baroroh Iskhamdhanah, 2023; Primasari et al., 2020).

This research highlights the critical finding that internal factors, such as motivation, interest, and self-efficacy, and external factors, such as classroom climate, learning quality, and parental support, significantly shape students' literacy abilities (Harlen & Qualter, 2018; Shernoff et al., 2017). In science learning in elementary schools, the influence of these two types of factors is significant because they interact and reinforce each other, forming a solid foundation for the development of students' scientific literacy. With a better understanding of how these factors influence learning, a more holistic and focused approach can be taken to improve students' scientific literacy in the future.

Conclusion

This research confirms that students' scientific literacy abilities can be influenced positively and significantly by various factors, both internal and external. Internally, students' motivation, interest and self-efficacy are crucial in shaping their ability to understand and apply scientific concepts. On the other hand, external factors such as classroom climate, learning quality, and parental support also significantly contribute to students' scientific literacy. Science learning in elementary schools must be an effective forum for exploring and developing students' scientific literacy. In facing the challenges of the 21st century, scientific literacy abilities cannot be underestimated. Scientific literacy is essential for students to understand and apply scientific concepts in everyday life and adapt to ever-growing technological and information developments. With innovative and technology-based learning strategies, teachers can encourage students to think critically, creatively, and collaboratively. Learning that is interactive and relevant to the real world will help students develop the scientific skills they need to be successful in the future. With the proper support from the learning environment and family, students will be more motivated and confident in exploring the world of science, making them individuals who are scientifically literate and ready to face global challenges.

Research on students' scientific literacy skills in elementary schools needs to be expanded in scope to provide a more representative picture. This study only focuses on one area, namely Jakarta, Indonesia. By expanding the scope of the research area, the results obtained will better describe the actual conditions of students' scientific literacy skills in elementary schools in various regions. Further research is recommended to take samples from various areas, both urban and rural, as well as various provinces in Indonesia. The aim is to provide a more comprehensive understanding of students' scientific literacy skills in elementary schools in Indonesia. With a wider scope, it is hoped to provide a better and more accurate explanation of the variations in students' scientific literacy skills, as well as the factors that influence them in various geographical and social contexts.

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The Role of Story Maps in Improving Primary School Students' Skills in Determining the Main Idea in Narrative Texts*

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Abstract

The purpose of this study is to examine the effect of the story map method applied to fourth-grade primary school students on the students' ability to determine the main idea in narrative texts. The study was conducted within the scope of a quasi-experimental design, one of the quantitative research methods; a matched control group post-test model was used. The sample of the study consisted of a total of 80 students (experiment = 40, control = 40) studying at a public primary school in Antalya, Türkiye. The findings revealed that the students who received education with the story map method showed significantly higher success compared to the control group both at the sub-problem level and in total test scores. The high eta-squared values, in particular, showed that the application has a strong educational effect. This study shows that structured strategies with visual support, such as story maps, are effective for developing the skill of determining the main idea at the primary school level.

Keywords:

Story map, Reading comprehension, Determining the main idea, Visual learning strategies, Primary school students.

Introduction

Reading is a foundational cognitive activity that underpins individuals' ability to acquire knowledge, think critically, and express themselves effectively. One of the most essential outcomes of reading is the ability to accurately and meaningfully identify the main idea of a text. This skill plays a crucial role in students' reading comprehension, enabling them to make connections with the text and develop higher-order thinking abilities (Hudson et al., 2021). In narrative texts, identifying the main idea requires an understanding of the relationships among text elements and the ability to draw inferences.

In this context, various instructional strategies are employed in language education to help students improve their ability to identify the main idea. Story maps are visual tools that help students organize key components of narrative texts

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such as characters, setting, and events, supporting a deeper understanding of the story's main idea. This method enables students to move beyond surface-level comprehension and grasp the main idea more effectively (Praveen & Rajan, 2013; Sugandi et al., 2022).

Recent research confirms the positive impact of story maps on reading comprehension, particularly in primary education contexts (Beyhatın & Özdemir, 2023; Prasansaph, 2024). However, few studies have specifically examined their role in main idea identification.

However, most existing studies emphasize general reading comprehension rather than focusing specifically on the skill of identifying the main idea in narrative texts (Guo et al., 2020; Wulandari, 1970). This reveals a significant gap in the literature and highlights the need for targeted research on how structured visual strategies, such as story maps, support the development of main idea comprehension. Moreover, the integration of digital tools into story mapping is still in its early stages, and more empirical evidence is needed to assess their long-term effects and classroom adaptability (Chitsaz et al., 2023). There is also a limited representation of studies conducted in non-English language contexts, such as Turkish, within the international literature. Cultural and linguistic factors influencing strategy effectiveness remain underexplored. A recent meta-analysis by Peng et al.(2023), examining 52 reading comprehension studies, concluded that no single strategy is the most effective in isolation. Instead, the highest learning gains occur when main idea instruction is combined with text structure teaching and retelling practices. These findings highlight the importance of holistic approaches in reading instruction. They also raise new questions about the role of structured strategies like story mapping in teaching the main idea to younger learners. Given these gaps and the growing emphasis on integrated instructional approaches, the need for focused empirical studies has become increasingly evident.

This study aims to address these gaps by examining the effectiveness of the story mapping method in improving fourth-grade students' ability to identify the main idea in narrative texts. In line with these objectives, this study seeks to answer the following research questions:

- Does the story map method significantly improve students' ability to identify the main idea in narrative texts compared to traditional teaching methods?
- What is the extent of the educational impact of the story map strategy on different sub-skills related to main idea identification?
- The findings are expected to provide new empirical evidence on the integrated use of visual strategies in Turkish language instruction and to offer practical insights for educators and curriculum developers.

Literature Review

The Development of Reading Comprehension Skills at the Primary School Level

During the primary school years, reading comprehension goes beyond basic language skills to encompass students' ability to make meaning from text and construct knowledge. During this period, students not only improve their decoding (phonics) skills but also vocabulary knowledge, prior knowledge utilization and text comprehension strategies. Duke et al., (2021) emphasize that reading comprehension instruction should begin at an early age, as it is not an automatic process; even fluent readers need explicit guidance supported by skills such as reading fluency, vocabulary, and cognitive flexibility to construct meaning effectively. While Duke et al. (2021) highlight the cognitive mechanisms behind comprehension, Dermitzaki (2025) draws attention to its long-term academic and social implications — both perspectives emphasize the need for structured instruction from early stages.

For this reason, systematic instruction in vocabulary, background knowledge, and text analysis is widely recognized as essential for both comprehension development and academic achievement (Dermitzaki, 2025). As a result, reading comprehension at the primary school level is a competency area that develops gradually through early intervention and the implementation of multifaceted skill-building strategies. These insights highlight the importance of structured and early reading instruction as a foundation for lifelong literacy development.

The Skill of Identifying the Main Idea and Instructional Approaches

The ability to identify the main idea in a text is one of the central components of the reading comprehension process. Students' capacity to grasp the main idea of a narrative or paragraph is closely linked to their ability to comprehend the text at a deeper level. Indeed, studies have shown that students who can identify the main idea and summarize it are able to understand and integrate the information in a more coherent and connected manner (Hudson et al., 2021). While Hudson et al. (2021) highlight the cognitive benefits of main idea identification for deeper comprehension, Williams et al. (2016) emphasize the instructional value of explicitly teaching this skill to support student success. This close link to higher-order comprehension underscores the importance of explicitly teaching main idea identification strategies in the classroom.

Studies emphasize that when teachers explicitly teach strategies for identifying the main idea and summarizing, it provides a strong foundation for the development of reading comprehension skills (Williams et al., 2016). This approach equips students with skills such as distinguishing important information from irrelevant details, expressing the main idea in their own words, and identifying supporting details. Structured questions (e.g., "What is the main idea of this text?") and summarization activities can be used to help students maintain focus. The literature indicates that such strategy instruction enhances elementary students' ability to identify main ideas and improves their overall reading comprehension. Taken together, these findings indicate that well-structured instruction in main idea identification not only enhances students' comprehension skills but also fosters critical thinking and metacognitive awareness.

The Story Mapping Method: Definition and Theoretical Foundations

A story map is a type of graphic organizer designed to visually organize the key elements of a narrative text (such as characters, setting, time, plot, conflict, and resolution) within a structured framework. The primary goal of this method is to direct students' attention to the essential components of the story, thereby facilitating their understanding of the storyline and the underlying structure of the text. Indeed, by presenting the plot of a narrative in a visual format, the story map helps students more easily identify and comprehend the critical information within the text (Sugandi et al., 2022). For instance, by mapping out characters, setting, and key events spatially, students can visually trace the narrative flow, which in turn helps them infer the main idea more easily.

Theoretically, story maps align with the constructivist approach to learning, offering a strategy in which students actively analyze and reconstruct the text to build their own understanding. Visual-spatial learning elements also play a significant role in this process. Visual learning refers to the process of acquiring and organizing knowledge through visual representations such as diagrams, charts, and spatial layouts. By transforming textual information into visual form, the story mapping method supports learning through both verbal and visual channels, in line with the dual coding theory. In fact, using graphic organizers helps students process complex information more easily; they can structure their thoughts and identify key relationships within the text, thereby enhancing both comprehension and memory retention (Prasansaph, 2024).

Story maps, as a form of visual learning, facilitate comprehension by externalizing the narrative structure in a spatial and hierarchical format. This visualization reduces cognitive load and enables students to organize and connect key elements of the story, such as characters, setting, and plot, ultimately supporting the identification of the main idea.

Story maps play a crucial role in making abstract narrative texts more concrete and accessible for students, thus facilitating the overall learning process. The strategy draws theoretical support from Vygotsky's (1978) concept of the zone of proximal development, offering a visual scaffold that, when guided by the teacher, helps learners develop higher-order comprehension skills. Therefore, story maps do not merely support visual learning in a general sense; they function as cognitively efficient tools that organize information in ways that align with how the brain processes and retains visual and verbal input simultaneously. As a result, story mapping emerges as an effective reading comprehension strategy that combines constructivist and visual learning principles. It is grounded in both cognitive theory and pedagogical practice.

The Role of the Story Mapping Strategy in Experimental Research (Post-2020)

In recent years, there has been a growing number of experimental studies examining the effectiveness of the story mapping strategy. A review of the post-2020 literature reveals that research conducted in various countries and among diverse student populations has demonstrated significant improvements in reading comprehension as a result of this approach. For instance, a study conducted in Türkiye found that first-grade students who regularly used story maps during lessons showed significantly higher levels of listening and reading comprehension than those in the control group (Beyhatın & Özdemir, 2023).

This study demonstrates that even young children who are at the early stages of developing reading skills can better grasp the main structure of a text and respond more accurately to comprehension questions through the use of story maps. Similarly, a study conducted with middle school students in Indonesia reported that implementing the story mapping strategy led to significant improvements in students' English reading comprehension scores (Sugandi et al., 2022).

In a different context, a single-subject study conducted in Iran with students experiencing reading difficulties and special educational needs also reported that instruction using story mapping led to noticeable improvements in students' reading skills (Chitsaz et al., 2023). The study observed improvements in students' sub-skills following the intervention, including text comprehension, sequencing of main events, and word recognition.

These findings confirm that the story mapping method is both applicable and effective for a wide

range of students, including those in English-speaking contexts as well as learners of English as a foreign language. Nonetheless, while these studies provide detailed evidence on the effectiveness of the method, they have also raised new questions in the literature regarding how variables such as frequency of use, duration, and method of integration influence learning outcomes.

While previous studies have focused on general improvements in overall comprehension or specific sub-skills such as sequencing and vocabulary (e.g., Chitsaz et al., 2023; Sugandi et al., 2022), the present study uniquely centers on students' ability to identify the main idea in narrative texts— a skill closely linked to higher-order comprehension. By targeting this specific dimension, our research highlights how story mapping can enhance not only general understanding but also critical comprehension components in upper primary students.

Story Mapping Applications through Digital Tools

With the advancement of modern educational technologies, there has been a growing body of research on the digital adaptation of graphic organizer strategies such as story mapping. Digital story mapping applications offer several advantages over traditional paper-and-pencil methods: students can create interactive story maps on tablets, computers, or smartboards, drag and drop characters or events from the text into schematic formats, and make adjustments as needed with ease. The literature provides evidence that using mobile software to create story maps can enhance the effectiveness of the strategy. For example, one study reports that students who used story mapping in a digital environment exhibited higher motivation and greater willingness to engage with the strategy compared to those who followed the traditional method (Chitsaz et al., 2023).

Using story maps through digital tools enriches students' visual learning experience by allowing them to incorporate multimedia elements such as images, icons, and color coding, thereby diversifying the learning process. For instance, interactive story map templates available on online platforms offer gamified activities that enable students to drag and drop key elements of the text into their appropriate positions. Such technology-enhanced approaches have been shown to increase engagement, particularly among digital natives, and make the strategy more appealing. However, comprehensive research on the effectiveness of digital story mapping remains limited. While initial findings are promising, questions regarding whether on-screen interaction with text introduces distractions or how it affects long-term learning outcomes still require further investigation. Nonetheless, the current literature suggests that technology-supported story maps offer an innovative contribution to reading comprehension instruction, especially in blended learning environments. While prior research has predominantly highlighted the motivational advantages of digital story mapping, this study specifically explores its pedagogical effectiveness in enhancing students' main idea identification skills—an essential component of reading comprehension.

Method

Research Design

This study was conducted to examine the effect of story maps on fourth-grade primary school students' ability to identify the main idea in narrative texts. The research adopted a pretest-posttest control group quasi-experimental design with matched groups, which is a subtype of quantitative research methods. Although the study was initially referred to as a post-test-only model, both pretest and posttest measurements were conducted to ensure the equivalence of the groups and to assess the effectiveness of the intervention. While quasi-experimental designs resemble true experimental designs in terms of measuring dependent variables, procedures, and experimental units, they differ in that participants are not randomly assigned to the experimental and control groups (Bulduk, 2003). Among four classrooms with similar average achievement scores in Turkish language courses, two were assigned as the experimental group and two as the control group. To assess both initial equivalence and the effects of the intervention, academic achievement data were collected from all groups before and after the implementation.

Study Group

The study group consisted of a total of 80 fourth-grade students enrolled at a public primary school in the Aksu district of Antalya, Türkiye, during the 2021–2022 academic year. Of these students, 40 were assigned to the experimental group and 40 to the control group. Each group included 22 female and 18 male students. The groups were formed based on the existing classroom structure, with careful attention paid to maintaining a balanced gender distribution.

It was confirmed that the participants had no prior exposure to the story mapping strategy before the implementation of the study.

To ensure group equivalence, students' average grades from Turkish language written exams in the first and second semesters were used as matching criteria. Statistical analyses (Shapiro-Wilk test and Mann-Whitney U test) confirmed no significant

difference in initial academic achievement between the two groups (U = 717.000, p = .424), indicating baseline equivalence.

Data Collection

In this study, the Reading Comprehension and Main Idea Identification Scale developed by Pilten (2007) was used to assess students' ability to identify the main idea in narrative texts. The scale was developed collaboratively by a Turkish language teacher, an assessment and evaluation specialist, and the researcher.

The first part of the scale served as the primary data collection tool for the study and consisted of open-ended questions designed to evaluate reading comprehension and main idea identification skills in narrative texts.

The scale consisted of eight open-ended questions addressing students' comprehension of narrative text elements such as the main idea, supporting details, characters, setting, and resolution. A sample item is: "What was the main problem in the story? How was it solved?" Responses were scored using a four-point rubric ranging from 0 (no response or irrelevant answer) to 4 (complete and accurate identification with textual justification). The rubric was developed based on expert feedback and was consistently applied by all raters.

To ensure content validity, expert opinions were obtained from two faculty members from the Departments of Classroom Teaching and Turkish Language Education at Gazi University, Faculty of Education.

To ensure the reliability of the scale, it was administered to a group of 67 students from the experimental and control groups. Student responses were independently scored by the researcher, a Turkish language teacher, and a classroom teacher. Inter-rater reliability coefficients were calculated, and the correlation coefficients among the raters ranged between 0.91 and 0.98, indicating that the scale was highly reliable. Ethical approval was obtained for the use of the data collection tool in the study.

Implementation Process

The implementation process of the study was carried out during the second semester of the 2021–2022 academic year . Based on pretest results and teacher evaluations, the classes were assigned to either the experimental or control groups.

Prior to implementation, classroom teachers in the experimental group received training on the story mapping strategy, including how to integrate it effectively into their instruction. Additionally, the researcher conducted two sample lessons directly in the experimental classrooms to model the implementation and ensure accurate application of the strategy.

The intervention lasted for a total of eight weeks. During this period, eight narrative texts appropriate for fourth-grade students were selected from Turkish language textbooks and children's magazines. In the experimental group, each text was taught through the story mapping strategy. After reading, students engaged in structured analysis of key narrative elements (including plot, characters, setting, problem, solution, and outcome) by completing story map templates designed to visually organize the components of the texts After reading, students analyzed key narrative elements such as plot, characters, setting, problem, solution, and outcome by completing story map templates designed to visually organize the texts. In the control group, the same texts were taught using traditional instructional methods, without the use of visual or structured strategies. Both groups studied the texts simultaneously, each group following its respective instructional approach.

Throughout the implementation process, no changes occurred in classroom composition or teaching personnel, and the study was completed as planned.

Data Analysis

In the analysis of the data obtained from the study, the initial step involved evaluating the equivalence of the experimental and control groups by using the students' Turkish course written exam scores. The averages of the second written exam in the first semester and the first written exam in the second semester were calculated to form the groups, and distribution characteristics of the scores were then analyzed. For this purpose, measures of central tendency (mean, median, mode), skewness and kurtosis coefficients were computed, and the Shapiro-Wilk test was applied to assess normality.

The results revealed that the scores in the experimental group did not follow a normal distribution ($p < .001$), whereas the control group showed skewness of -0.770 and kurtosis of -0.084. The Shapiro-Wilk test for the control group indicated that the assumption of normality was met (p = .015). Based on these findings, the Mann-Whitney U test was conducted to assess differences in initial levels between the two groups, revealing no statistically significant difference (U = 717.000, p = .424). This result suggests that the experimental and control groups were academically equivalent at the outset.

Normality tests were also conducted on the data collected through the Reading Comprehension and Main Idea Identification Scale. The analyses based on sub-problems indicated that while some datasets met the normality assumption, others did not. Accordingly, for sub-problems that met the assumption, independent samples t-tests were used, whereas Mann-Whitney U tests were employed for those that did not.

All statistical analyses were performed using SPSS 25.0, and the level of significance was set at .05. Additionally, eta-squared values were calculated to assess the magnitude of the observed differences. For instance, an eta-squared value of 0.60 indicates a large effect size, suggesting that the story map method had a strong educational impact on students' ability to determine the main idea. Descriptive statistics related to the data are presented below (see Table 1).

Assumptions and Limitations of the Research

Assumptions

The following assumptions were adopted:

- It was assumed that all participating students responded to the measurement tools honestly and attentively.
- The teachers of both the experimental and control groups implemented the instructional process in accordance with the designated teaching methods.
- The "Reading Comprehension and Main Idea Identification Scale" used in the study was assumed to be valid and reliable.
- During the intervention, students were exposed only to the instructional methods assigned to their group and were not influenced by external factors.

Limitations

The findings of this study should be interpreted within the scope of the following limitations:

- The study was limited to fourth-grade students at a primary school located in the Aksu district of Antalya, Türkiye, during the second semester of the 2021–2022 academic year.
- The participants consisted solely of fourth-grade students; therefore, the results cannot be generalized to students at other grade levels.
- The duration of the intervention was limited to eight weeks.
- The data collection instrument focused exclusively on measuring students' ability to identify the main idea in narrative texts; other reading comprehension skills were not assessed.
- The implementation of the story map method may have been influenced by the classroom teacher's instructional style and classroom management, potentially affecting the results.
- Differences in the complexity and content of the narrative texts used during the sessions might have introduced uncontrolled variables.

As the study was limited to a short-term intervention, the long-term effects of the story map strategy were not evaluated; therefore, conclusions about its lasting impact cannot be drawn.

Ethical Considerations

The research process was conducted in accordance with the principles of scientific research and publication ethics. Prior to implementation, ethical approval was obtained from the Ethics Committee for Scientific Research and Publication in Social and Human

Table 1.

Descriptive Statistics for the Scores of the Reading Comprehension and Main Idea Identification Scale

Sub-Problem	Group	Mean	Median	Mode	Skewness	Kurtosis	Shapiro-Wilk *p*-value |
Sub-Problem 1	Experimental Group	4.698	4.75	4.63	-0.585	-0.267	0.075
Sub-Problem 1	Control Group	4.237	4.271	4.63	-0.656	-0.336	0.025
Sub-Problem 2	Experimental Group	4.289	4.417	4.63	-1.623	3.088	0
Sub-Problem 2	Control Group	3.452	3.563	3.63	0.087	0.105	0.678
Sub-Problem 3	Experimental Group	4.437	4.48	4.63	-0.575	-0.696	0.019
Sub-Problem 3	Control Group	3.655	3.729	3.63	-0.456	-0.572	0.177
Sub-Problem 4	Experimental Group	4.126	4.208	4.13	-1.242	2.572	0.004
Sub-Problem 4	Control Group	3.152	3.313	3.75	-0.983	1.843	0.06
Sub-Problem 5	Experimental Group	3.996	4.021	3.88	-0.434	-0.041	0.525
Sub-Problem 5	Control Group	2.758	2.729	3.38	0.251	-0.252	0.728
Sub-Problem 6	Experimental Group	4.172	4.208	3.88	-0.38	0.077	0.727
Sub-Problem 6	Control Group	3.263	3.229	3.38	0.441	0.353	0.715
Sub-Problem 7	Experimental Group	3.806	3.813	4.25	-0.593	0.169	0.288
Sub-Problem 7	Control Group	2.371	2.25	2.17	0.141	-0.52	0.591
Sub-Problem 8	Experimental Group	3.975	4.042	3.75	-0.737	-0.199	0.015
Sub-Problem 8	Control Group	2.75	2.813	2.5	-0.433	-0.426	0.194
Total Score	Experimental Group	41.668	42.542	42.96	-0.674	-0.525	0.012
Total Score	Control Group	32.199	31.833	31.17	-0.079	0.172	0.765

Sciences at Akdeniz University (Decision No: 161, dated 20.04.2022). Additionally, institutional permissions were secured from the school administration and classroom teachers where the study was to be conducted. Written informed consent forms were collected from the parents of the students, and participation was based on voluntary involvement. It was clearly stated to the students that they had the right to withdraw from the study at any time if they wished. Throughout the data collection and analysis process, strict adherence to the principles of confidentiality and anonymity was maintained.

Findings

Findings Related to the First Sub-Problem

The results indicated that the experimental group outperformed the control group in identifying the main idea and its sub-components, including the problem, events, and resolution. Notably, certain sub-skills—such as identifying the problem and recognizing the resolution—showed greater improvement than others. This may be attributed to the structure of the story map method, which emphasizes the narrative flow and problem-resolution framework, helping students internalize these components more effectively. In contrast, elements like setting or character traits may require different scaffolding strategies, which were less emphasized in the intervention. Table 2 indicates a statistically significant difference in the mean scores of Question 1 between the experimental and control groups, $t(55.884) = 6.013$, $p = .001$, $\eta^2 = .32$. The mean score of the experimental group ($M = 4.698$) was higher than that of the control group ($M = 4.237$). The calculated eta-squared value indicates a large effect size, suggesting that the story map strategy had a strong educational impact on students' ability to identify the main idea.

Findings Related to Second Sub-Problems

Table 3 shows that there is a statistically significant difference between the experimental and control groups in terms of the mean scores for Question 2, $t(78) = 7.544$, $p < .001$, $\eta^2 = .42$. The mean score of the experimental group ($M = 4.289$) was higher than that of the control group ($M = 3.452$). The calculated eta-squared value indicates that the difference corresponds to a large effect size.

Findings Related to the Third Sub-Problem

Table 4 reveals that there is a statistically significant difference between the mean scores of the experimental and control groups for Question 3 ($t(65.923) = 8.187$, $p < .001$, $\eta^2 = .46$). The experimental group achieved a higher mean score ($M = 4.437$) compared to the control group ($M = 3.655$). The eta-squared value of .46 indicates a large effect size, suggesting that the story map strategy had a strong practical impact on students' ability to identify the problem in narrative texts.

Findings Related to the Fourth Sub-Problem

Table 5 displays a statistically significant difference in the mean ranks between the experimental and control groups for Sub-Problem 4 ($U = 171.000$, $p = .001$). The experimental group achieved a notably higher mean rank (56.21) than the control group (24.79). This suggests that the story map strategy effectively enhanced students' comprehension in this specific sub-skill area, reinforcing its potential as a supportive visual aid in narrative structure learning.

Findings Related to the Fifth Sub-Problem

As presented in Table 6, there is a highly significant difference in the mean scores between the experimental and control groups for Question 5 ($t(78) = 10.938$, $p < .001$, $\eta^2 = .61$). The experimental group attained a notably higher average score ($M = 3.996$) compared to the control group ($M = 2.758$). With an eta-squared value of .61, this result reflects a very large effect size, underscoring the strong educational impact of the story map strategy on students' ability to grasp this specific narrative element. This finding may indicate that students benefit most when visual tools are aligned with cognitively demanding sub-skills.

Findings Related to the Sixth Sub-Problem

Table 7 demonstrates a statistically significant difference in favor of the experimental group regarding Question 6 ($t(78) = 8.221$, $p < .001$, $\eta^2 = .46$). The experimental group's mean score ($M = 4.172$) exceeded that of the control group ($M = 3.263$), indicating a marked improvement in students' comprehension of this narrative component. The eta-squared value (.46) reflects a large effect size, suggesting that the story map intervention effectively supported learners in organizing and interpreting key story elements. This reinforces the pedagogical value of integrating visual scaffolding techniques into language instruction.

Findings Related to the Seventh Sub-Problem

Table 8 reveals a statistically significant difference between the mean scores of the experimental and control groups on Question 7 ($t(78) = 9.003$, $p < .001$, $\eta^2 = .51$). The experimental group attained a considerably higher mean score ($M = 3.806$) than the control group ($M = 2.371$). The eta-squared value of .51 signifies a large effect size, indicating that the story map strategy had a strong educational influence on students' ability to process and articulate this sub-skill. This outcome underscores how structured visual tools can facilitate deeper engagement with narrative components, particularly when learners are required to infer and synthesize story meaning.

Findings Related to the Eighth Sub-Problem

Table 9 shows a statistically significant difference in the mean scores of the experimental and control groups for Question 8 ($t(78) = 10.837$, $p < .001$, $\eta^2 = .60$). Students in the experimental group achieved a notably higher mean score ($M = 3.975$) than those in the control group ($M = 2.765$). An eta-squared value of .60 represents a very large effect size, pointing to a substantial educational benefit of the story map strategy in developing students' skills related to this sub-component. Such a result suggests that integrating structured visual tools into reading instruction may significantly enhance learners' ability to comprehend and retain complex narrative elements.

Findings Related to the Overall Test Scores

Table 10 demonstrates a statistically significant difference in the total test scores between the experimental and control groups ($t(78) = 13.142$, $p < .001$, $\eta^2 = .69$). The experimental group achieved a markedly higher mean total score ($M = 41.668$) compared to the control group ($M = 32.199$). The eta-squared value of .69 indicates a very large effect size, suggesting that the story map intervention had a powerful and comprehensive impact on overall reading comprehension performance. This finding underscores the potential of visual-organizational strategies to yield significant learning gains when systematically implemented in elementary reading instruction.

Table 2.

Independent Samples t-Test for the Comparison of Scores on Question 1

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	4.698	0.209	0.461	6.013	55.884	0.001	0.32
Control	40	4.237	0.438					

Table 3.

Independent Samples t-Test for the Comparison of Scores on Question 2

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	4.289	0.437	0.836	7.544	78	0.001	0.42
Control	40	3.452	0.549					

Table 4.

Independent Samples t-Test for the Comparison of Scores on Question 3

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	4.437	0.323	0.781	8.187	65.923	0.001	0.46
Control	40	3.655	0.51					

Table 5.

Mann-Whitney U Test for the Comparison of Scores on Sub-Problem 4 Between Experimental and Control Groups

Group	*n*	Mean Rank	*U*	*p*
Experimental	40	56.21	171	0.001
Control	40	24.79		

Table 6.

Independent Samples t-Test for the Comparison of Scores on Question 5

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	3.996	0.435	1.238	10.938	78	0.001	0.61
Control	40	2.758	0.568					

Table 7.

Independent Samples t-Test for the Comparison of Scores on Question 6

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	4.172	0.41	0.909	8.221	78	0.001	0.46
Control	40	3.263	0.567					

Table 8.

Independent Samples t-Test for the Comparison of Scores on Question 7

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	3.806	0.653	1.435	9.003	78	0.001	0.51
Control	40	2.371	0.768					

Table 9.

Independent Samples t-Test for the Comparison of Scores on Question 8

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	3.975	0.472	1.21	10.837	78	0.001	0.6
Control	40	2.765	0.526					

Table 10.

Independent Samples t-Test for the Comparison of Total Test Scores

Group	*n*	*M*	*sd*	Mean Difference	*t*	*df*	*p*	η^2
Experimental	40	41.668	2.656	9.469	13.142	78	0.001	0.69
Control	40	32.199	3.703					

Discussion

The findings of this study clearly indicate that the story map strategy significantly enhances fourth-grade students' ability to identify the main idea in narrative texts. Students in the experimental group consistently outperformed their peers in the control group across all sub-problems, and the effect sizes were predominantly high. These results support the conclusion that story mapping functions as a powerful visual learning tool. This finding is consistent with prior research that highlights the contribution of story maps to the comprehension of narrative texts. For instance, a study conducted by Özkara and Şahin (2013) with fifth-grade students reported that those taught using the story map strategy performed significantly better in identifying the main idea compared to students in the control group who were instructed through traditional methods (Özkara & Şahin, 2013). This finding parallels the superiority of the experimental group in identifying the main idea observed in our study. Similarly, studies conducted by Akça (2002) and Işıkdoğan (2009) also emphasized that the story mapping strategy significantly improved students' reading comprehension skills compared to traditional instructional methods.

This positive impact on reading comprehension is also supported by recent studies in literature. In particular, studies conducted in recent years have demonstrated that story mapping enhances students' ability to understand narrative texts and identify main ideas across diverse student populations. For instance, in a study by Alturki (2017) involving sixth-grade students with specific learning disabilities who were learning English as a second language, it was found that group-based story mapping activities significantly facilitated students' comprehension of the texts (Alturki, 2017).

This study is significant in that it highlights the effectiveness of story mapping not only for typically developing students but also for those who require additional support. Other international studies conducted with students with learning disabilities have also reported similar findings. For example, Boulineau et al. (2004) and Gardill & Jitendra, (1999) found that the story map strategy substantially improved students' understanding of story grammar elements and their overall narrative comprehension.

In a study conducted by Hwang and Park (2004) with elementary school students experiencing reading difficulties, it was found that the experimental group receiving story map instruction significantly outperformed the control group in reading comprehension tests. These findings further strengthen the evidence that story mapping is a beneficial instructional strategy for improving narrative text understanding, especially among learners with reading challenges.

Taken together, the existing literature consistently supports the positive influence of story mapping on narrative comprehension and the identification of main ideas. There is broad consensus that this visual and structured approach enhances students' abilities to process and internalize key story elements. However, alongside this consistency, it is also important to address the areas where our findings diverge from or add nuance to prior research.

Notably, some studies have indicated that the effectiveness of story mapping may vary depending on the specific sub-skills being targeted. For instance, in a study by Özkara and Şahin (2013), it was reported that students in the experimental group showed significantly better understanding of core elements such as the main character, setting, and time. However, for sub-skills like identifying supporting or minor characters, there was no significant difference between the experimental and control groups. This suggests that while story maps are generally effective, their impact may be more pronounced in organizing central narrative components than in recalling peripheral details.

In contrast to the aforementioned studies, our research revealed statistically significant differences in favor of the experimental group across all assessment criteria. A likely explanation for this comprehensive effect is the focused nature of our intervention, which specifically targeted the development of students' ability to identify the main idea—a higher-order cognitive skill. The story mapping activities used in our study were systematically designed to support this skill, rather than simply aiding general comprehension.

Identifying the main idea involves extracting the central message or theme of a text, a process that does not always occur spontaneously for young readers. As Pilten (2007) emphasizes, students often require explicit support through metacognitive strategies to accurately and fully determine the main idea. The structured visual framework provided by story maps in our study appears to have facilitated this process by helping students organize key elements of the narrative in a meaningful way, thereby improving both comprehension and inferencing.

In this context, the story map strategy functions as a metacognitive tool by structurally guiding students through the process of identifying the main idea step by step. The high effect sizes observed in this study indicate that such structured support contributes significantly not only in statistical terms but also in pedagogical effectiveness. According to Cohen's (2013) classification, effect sizes of 0.80 and above are considered "large," which suggests that the use of story maps creates a meaningful and practical difference in students' learning outcomes.

One possible reason for this strong effect may be the systematic, well-planned, and intensive implementation of story map instruction in the experimental group. As students repeatedly practiced identifying key narrative elements and the main idea through mapping during the intervention period, they may have internalized the strategy and developed deeper processing skills. In contrast, studies with shorter duration or limited implementation have reported more modest effects. For instance, in a case study conducted by Babyak et al. (2000), where students used story mapping with only a single narrative text, it was found that some core elements were not fully understood, and the overall impact remained limited.

Therefore, the effectiveness of the story mapping strategy may vary depending on the duration, scope, and the specific skills targeted during the implementation. Our findings suggest that a comprehensive and goal-oriented application yields the greatest benefits. When examined in light of the literature on cognitive processes, story maps appear to facilitate the reading comprehension process by supporting both the organization of information and memory retention. In general, graphic organizers help students engage in deeper text processing by presenting information in a visual and hierarchical manner (Jiang & Grabe, 2007).

Specifically, a story map presents the fundamental elements of a narrative—such as characters, setting, time, problem, events, resolution, and main idea—in a structured format. This external organizational tool enables students to select and arrange key information from the text and to visualize the relationships between these elements.

Indeed, Jiang and Grabe (2007) noted that the use of graphic organizers in this way facilitates the processes of text comprehension, memory retention, and establishing connections between pieces of information .

In this regard, story mapping can help reduce students' cognitive load and redirect their attention toward grasping the main idea of the text. The process of creating a story map also encourages students to consistently ask themselves, "What are the key elements of the story? What is the main idea?" while reading. This functions as a form of active reading and metacognitive monitoring strategy. In order to complete the map, students must read the text attentively and distinguish between main and supporting elements. During this process, they focus less on superficial details and more on the deep structure of the text; they discuss relationships between characters, cause-and-effect links within the plot, and the significance of the resolution. As a result, this deeper processing facilitates the identification of the main idea, since all essential components of the story are mentally organized into a coherent whole. This is supported by the classic study conducted by Amlund et al. (1985), which demonstrated that fifth- and sixth-grade students with both strong and weak reading skills performed significantly better in recalling the story when they used a story map during listening, compared to peers who only listened to the story.

Researchers emphasized that this improvement was linked to the story map's ability to strengthen story memory and highlight key elements. The increased success in identifying the main idea observed in our study can similarly be attributed to this mechanism: students who used story maps were able to internalize the narrative structure more effectively within their mental models, enabling them to grasp the author's intended message or theme with greater clarity. Another important aspect to consider is the functionality of story maps across different student grade levels. While our study was conducted with fourth-grade students and yielded significant benefits at this level, the effectiveness of this strategy is not confined to a specific grade. Research findings suggest that the story mapping method can be adapted for use with various age groups starting from the early years of primary education. For instance, a study by Franciscone (2008) conducted with first-grade students reported that integrating story maps into reading comprehension instruction contributed positively to students' reading performance.

Naturally, as students' age decreases, story mapping applications are expected to be simpler and more visually oriented, with more intensive teacher guidance. Indeed, at preschool and early primary levels (grades 1–2), story maps are typically constructed with visual elements or through teacher-led scaffolding. From grade 4 onwards, however, students increasingly demonstrate the ability to independently identify and record key story elements in writing. Furthermore, the benefits of story mapping continue at the middle school level. In a comparative study conducted with eighth-grade students, Wulandari (2019) found that students who engaged in reading activities using the story map technique showed significant improvement in reading comprehension. The study also revealed that story mapping was as effective as other constructivist techniques, such as mind mapping, in enhancing comprehension. Both strategies led to increased understanding, with no statistically significant difference in their impact.

This finding indicates that story maps can serve as an effective instructional tool not only at the primary level but also in higher grade levels. Moreover, when considering their functionality across different learner profiles, it is important to emphasize the particular value of story maps for students with lower academic performance or special educational needs. The

literature reports noticeable improvements in narrative comprehension following story map instruction among students with learning difficulties (Stetter & Hughes, 2010) or behavioral challenges (Babyak et al., 2000). For instance, in a case study involving four students with problem behaviors, Babyak et al. (2000) observed that story map instruction generally enhanced students' performance on story comprehension questions.

These studies suggest that beyond offering cognitive support, story maps may also be beneficial in helping students structure their attention and stay motivated to learn. Indeed, in our study, an increase in student engagement and motivation was observed within the experimental group. Qualitative observations indicated that students participated enthusiastically in story mapping activities and engaged more deeply with the texts. This supports the notion that story maps are adaptable to students with varying levels and needs, and function effectively across different groups. Based on these findings, several implications can be drawn regarding the integration of the story mapping strategy into the instructional process.

These findings carry important implications for classroom practice. Teachers are encouraged to move beyond traditional reading comprehension methods and integrate story mapping as a core instructional strategy. This includes not only distributing story map templates but also explicitly modeling how to use them effectively. Implementing the gradual release of responsibility model ("I do, we do, you do") can support students in internalizing the technique. Moreover, integrating digital story mapping tools may increase engagement and support learners with diverse needs. Ultimately, teachers should consider story maps not as supplementary aids but as essential tools for developing students' higher-order comprehension skills, particularly in identifying main ideas in narrative texts. First, for the strategy to be effective, it must be implemented in a planned and intentional manner within the classroom setting. Teacher guidance is particularly critical in the initial stages. Jiang and Grabe (2007) also emphasized that for graphic organizers to be beneficial, students must be explicitly taught how to use these tools.

In this context, it is recommended that teachers go beyond merely distributing story maps as worksheets and instead model their use by demonstrating how to complete them step by step, guiding students throughout the process. For optimal integration, the gradual release of responsibility model ("I do, we do, you do") may be particularly effective. Initially, the teacher can read a narrative text aloud to the class and collaboratively fill in the story map on the board, highlighting key elements (a teacher-led guided activity). In the next stage, students can work in groups to map a similar text, and finally, they can be encouraged to create story maps individually. Such a structured progression allows students to internalize the strategy and apply it independently. As emphasized in Alturki's (2017) study, implementing story maps as a group activity offers students the opportunity to interact with peers, thereby enhancing their meaning-making processes.

Today, it has become possible to create interactive story maps using smart boards, tablet applications, or projection systems. Such digital implementations can be particularly motivating for students who experience attention difficulties or require greater visual stimulation. However, it is essential that pedagogical intent remains at the forefront when integrating technology. What matters most is not whether the map is created digitally or on paper, but whether the student is actively engaged in analyzing the text. Teachers incorporating story mapping into their lesson plans should adopt a holistic approach that includes reading the text, completing the story map, and subsequently engaging in a discussion of the main idea. This approach helps embed the story map activity as a natural part of the instructional flow, allowing students to perceive it not as an additional task, but as an integral component of the reading process. Indeed, the significant effects revealed by our study can be attributed to the regular and purposeful implementation of the strategy. Since the story mapping was applied only in the experimental group and for the duration of the intervention, it produced a noticeable difference; thus, adopting this strategy more permanently in curricula could lead to similar or even more sustained outcomes.

In conclusion, when the findings of our study are considered alongside the relevant literature, it is evident that the story map strategy is highly effective in enhancing fourth-grade students' ability to identify the main idea in narrative texts. The significantly higher performance of the experimental group, coupled with the large effect sizes observed, indicates that this strategy offers not only statistically significant but also educationally meaningful benefits. The consistency of our findings with a broad range of national and international studies further strengthens the credibility and generalizability of the results. As a visual learning tool, story maps support students' cognitive processes by helping them structure information, distinguish the main idea and key elements, and develop a more coherent understanding of the entire text. Particularly in fostering higher-order comprehension skills such as identifying the main idea, the use of story mapping is a pedagogical approach that is widely recommended in the literature (Pilten, 2007; Reed & Vaughn, 2012).

In addition to its direct impact on comprehension, the story map strategy also offers indirect benefits such as increasing student engagement and making the

learning process more enjoyable. In our study, students who used story maps demonstrated noticeably improved attitudes toward reading activities. Previous research also supports this finding. Students using story maps often score higher in reading attitude scales.

This also points to the motivational benefits of the method. Like any instructional strategy, however, the effective use of story maps depends on several factors, such as the level of teacher guidance, the suitability of the selected texts, students' prior knowledge, and time constraints—all of which may influence the extent of the strategy's impact. Nevertheless, the findings of this study suggest that the story mapping strategy can be adopted as a powerful learning tool at the primary school level, both theoretically and practically. These results highlight the significance of visualization and structured strategies in Turkish language education and can inform future research aimed at enhancing reading comprehension skills. Specifically, future studies may explore the long-term effects of story maps on students who struggle with identifying the main idea, their applicability to different genres (e.g., informational texts), or the outcomes of digital story mapping applications. In conclusion, the evidence presented in this study strongly demonstrates that story maps contribute meaningfully to narrative comprehension and significantly improve students' ability to identify the main idea by supporting cognitive processes and increasing student engagement. Incorporating evidence-based strategies such as story mapping into early reading instruction is consistent with both our findings and current educational practices.

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EthnoSTEM-based Learning Tools: Connecting Cultural Heritage with STEM Education

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Abstract

The integration of indigenous knowledge, cultural practices, and traditional ecological knowledge with science, technology, engineering, and mathematics (STEM) education has gained recognition as EthnoSTEM. This article explores the potential of developing EthnoSTEM-based learning tools to bridge the gap between cultural heritage and scientific knowledge in education. The stages of development in this study are preliminary investigation, design, and construction. The data collection technique involved using an instrument validated by experts The result of this development study provides an understanding of EthnoSTEM by defining its core concepts and illustrating its value in education. The benefits of EthnoSTEM-based learning tools to promote cultural diversity in STEM education fostering a more holistic learning experience by integrating cultural perspectives. The development of EthnoSTEM-based learning tools demonstrated strong validity, with expert validation scores averaging 4.5 out of 5, indicating high acceptability and alignment with pedagogical and cultural objectives. Furthermore, implementation in classrooms revealed a measurable impact on student engagement, which increased by 30% compared to conventional methods. These results underscore the effectiveness of integrating cultural heritage into STEM education, fostering both academic achievement and cultural appreciation. The study highlights the potential of EthnoSTEM approaches to create more inclusive, meaningful, and dynamic learning environments.

Keywords:

Cultural Heritage, Ethoscience, STEM, Learning Tools, Scientific Knowledge

Introduction

In recent decades, STEM (Science, Technology, Engineering, and Mathematics) education according to Basu & Barton (2010) has faced growing criticism for its often Eurocentric, decontextualized approach, which fails to resonate with students from diverse cultural backgrounds. This disconnect has contributed to persistent achievement gaps and underrepresentation of indigenous and minority groups in STEM fields according to Foundation (2021). In response, a transformative pedagogical framework based on Rosa & Orey (2011) has emerged: EthnoSTEM, which integrates

cultural heritage and indigenous knowledge systems with formal STEM education. The theoretical foundation of EthnoSTEM draws from culturally responsive pedagogy (Gay, 2018), place-based learning (Gruenewald, 2003), and social constructivism (Vygotsky, 1985), emphasizing that knowledge construction is most effective when rooted in learners' lived experiences. Recent studies, Kovach (2009) and Medin Bang (2014), demonstrate that EthnoSTEM approaches not only improve academic performance but also enhance cultural identity preservation and community engagement. For instance, The study conducted by Hunter et al. (2018) in New Zeland showed that incorporating Maori navigation techniques into geometry lessons increased Maori students' achievement by 25%.

The integration of EthnoSTEM into science learning is a groundbreaking approach that recognizes and values the diverse knowledge system and cultural practices surrounding science. EthnoSTEM refers to the indigenous, traditional, and local knowledge systems that have been passed down through generations in various communities. By integrating EthnoSTEM into science learning, we acknowledge the existence and importance of alternative perspectives and ways of knowing in the field of science. According to Pertiwi et al. (2018) EthnoSTEM integration not only enriches the learning experience but also promotes cultural diversity and inclusivity within the scientific community. It allows for a more holistic understanding of scientific concepts and phenomena, as EthnoSTEM offers unique insights and approaches that may differ from mainstream scientific methods

EthnoSTEM is a combination of indigenous knowledge with STEM education. Battiste (2005) and Duit (2007) explain that indigeneous knowledge (also known as folk knowledje) as well as Western science and traditional ecological knowledge, contribute to a broader understanding of the natural world.. Meanwhile, Rist Dahdouh-Guebas (2006) and Zidny et al (2021) defined indigenous knowledge as an education system that originates from a local perspective relating to the classification of objects and activities of natural phenomena that have been passed down from ancestors. Furthermore, Shernoff et al. (2017) and Le et al. (2019) regarding STEM education, currently STEM education is increasingly popular among educators along with advances in technology in the 21st century. According to Ha et al. (2020) STEM education is an interdisciplinary approach to the learning process that integrates academic principles with real-world experience. Hsu Yeh (2019) said that STEM education allows students to apply their knowledge in the fields of science, technology, engineering and mathematics contextually, Through this, they can establish connections between school, the world of work and the global community, so that with STEM education students can be able to compete in the current era of globalization.

As explained by Sumarni et al. (2020) indigenous knowledge and STEM are two things that are very different and far apart, this problem provides a solution by uniting culture and STEM as a way to improve the quality of education. According to Simpson et al. (2023) the perspective of indigenous people based on indigenous knowledge about STEM emphasizes seeing and being one with nature, because nature gives us gifts and teachings. Examples from the study by Garcia-Olp et al., (2022) within this point of view include circles drawn from round trees, the cycle of life and our round eyes, and other examples may include pinecones which are arranged in a spiral and lined up look like the Fibonacci series in mathematics. Therefore, as explained by Eglash et al. (2020) and Garcia-Olp et al. (2022) in their research, we see benefits in researching the integration of indigenous knowledge with STEM concepts, practices and processes to improve the quality of education.

Integrating EthnoSTEM into science learning fosters a sense of pride and ownership among communities, empowering them to actively participate in scientific research and decision-making processes. Jamaluddin et al. (2019) and Riyadi et al. (2018) explain that we create a more inclusive, equitable, and culturally responsive scientific environment that respects and embraces the richness of diverse knowledge systems. The bridging of cultural and scientific knowledge in the field of science is of utmost importance. Science itself is a universal language that transcends borders, but it is crucial to recognize and appreciate the cultural diversity that exists within scientific communities. Sumarni et al. (2016) explained that through the development of a science knowledge curriculum that is integrated with indigenous knowledge, it can indirectly strengthen students' spirit of nationalism.

By integrating cultural knowledge into scientific research and understanding, we can achieve a more comprehensive and holistic approach to solving complex problems. Based on Florida et al. (2015) and Johnson and Johnson (2014), cultural insights and perspectives offer unique ways of thinking and approaching scientific challenges, enabling a deeper understanding of various phenomena. Furthermore, bridging cultural and scientific knowledge fosters collaboration and promotes inclusivity within the scientific community, creating an environment where diverse ideas and perspectives are valued. According to Fatmawati (2011) integrating ethnoSTEM enhances scientific research and innovation but also contributes to the development of more effective solutions that are applicable across different cultures and contexts. By recognizing the interplay between cultural and scientific knowledge, we can enrich our collective

understanding of the world and work towards a more inclusive and sustainable future.

EthnoSTEM-Based Learning Tools are the materials, activities, and methods used in the classroom or in fieldwork that help facilitate this integration. These tools aim to teach students about the scientific aspects of natural resources, especially plants, while also acknowledging the cultural significance and traditional uses of those resources. Patmawati et al. (2019) said that exploring the potential of EthnoSTEM-based learning tools in education holds immense promise for transforming traditional teaching practices and empowering students from diverse cultural backgrounds. EthnoSTEM refers to the integration of indigenous knowledge, cultural practices, and traditional ways of knowing into STEM (Science, Technology, Engineering, and Mathematics) education. By incorporating EthnoSTEM-based learning tools, educators can create inclusive and culturally responsive classrooms that celebrate the wealth of knowledge that exists within different communities. One major advantage of using ethnoSTEM learning tools based on Sund and Trowbridge (1973) provides a bridge between students' cultural heritage and their formal education. As stated by Gormally et al. (2009) these tools enable students to see connections between their own cultural experiences and STEM subjects, making the learning process more meaningful and engaging. Additionally, EthnoSTEM-based learning tools challenge Eurocentric perspectives by acknowledging and valuing local knowledge systems, which fosters a sense of belonging and pride in students who may have felt marginalized or excluded in traditional educational settings.

Despite these advances, critical gaps remain in the literature according to Nasir et al. (2021). First, most EthnoSTEM research has focused on primary education, with limited application in secondary and tertiary levels. Second, while qualitative studies abound, there is a scarcity of large-scale quantitative evidence measuring the longitudinal impact of EthnoSTEM interventions. Third, few studies have developed systematic frameworks for teachers to adapt EthnoSTEM principles across different cultural contexts. For instance, McCarty and Lee (2014) and Smith (2021), by grounding STEM education in cultural relevance, contribute to the global movement for educational decolonization while offering empirically tested strategies to make STEM more inclusive and effective for diverse learners. The findings have implications for curriculum designers, policymakers, and educators seeking to harmonize traditional knowledge systems with 21st-century scientific competencies.

Despite growing interest in EthnoSTEM pedagogy, critical gaps persist in its application beyond primary education, empirical validation, and practical implementation. To address these gaps, this study seeks to answer the following questions: (1) How can EthnoSTEM be effectively adapted for secondary and tertiary STEM education to enhance cultural relevance and student engagement? (2) What is the longitudinal impact of EthnoSTEM interventions on both academic achievement and cultural identity development among diverse learners? and (3) What framework can guide educators in systematically integrating local cultural knowledge into STEM curricula across varying contexts? By investigating these questions, this research aims to advance a scalable, evidence-based EthnoSTEM model that bridges cultural heritage and STEM learning while empowering educators with actionable strategies.

Exploring EthnoSTEM-based learning tools can enhance critical thinking and problem-solving skills. According to Panasan and Nuangchalerm (2010) and Agung (2015) indigenous knowledge often offers alternative approaches and solutions that have been developed through centuries of observation and intergenerational sharing. Incorporating such knowledge allows students to develop a more holistic understanding of STEM topics and encourages them to think creatively when faced with complex challenges. Moreover, EthnoSTEM-based learning tools promote cultural diversity and intercultural dialogue. They expose students to different worldviews, traditions, and practices, fostering respect and appreciation for diverse cultures. This, in turn, cultivates an environment of inclusivity and helps break down stereotypes and biases. Aikenhead (2001) explains that the exploration of EthnoSTEM-based learning tools in education has tremendous potential to revolutionize teaching practices and nurture a generation of culturally competent and globally aware individuals. The research conducted by Sudarmin and Pujiastuti (2015) states that integrating diverse knowledge systems into STEM education, they encourage students to embrace their cultural heritage, develop critical thinking skills, and appreciate the value of different perspectives. Meanwhile Falah et al. (2018) and Fibonacci and Sudarmin (2014) believe that it is crucial for educators, curriculum developers, and policymakers to invest in researching, developing, and implementing EthnoSTEM-based learning tools to maximize the benefits for students from all cultural backgroundThe objective of this research is to develop and evaluate EthnoSTEM-based learning tools that effectively bridge the gap between cultural knowledge and scientific concepts. The aim is to create a more inclusive and culturally responsive educational experience for students, promoting a deeper understanding of both their cultural heritage and scientific principles. This study addresses these gaps by 1) proposing a scalable EthnoSTEM pedagogical framework validated through mixed-methods research; 2) providing quantitative

evidence of its impact on 50 students across multiple learning dimensions; and 3) developing practical tools for educators to bridge cultural heritage and STEM concepts.

In this research, STEM (Science, Technology, Engineering, and Mathematics) is redefined through the lens of EthnoSTEM pedagogy, where scientific concepts are taught in dialogue with indigenous and local knowledge systems. Unlike conventional STEM education that often prioritizes Eurocentric frameworks, this study embeds learning in cultural contexts—for example, analyzing the biochemical properties of traditional herbal drinks (jamu) to teach organic chemistry concepts or applying engineering principles to traditional jamu production techniques. Boz (2023) declares that his approach aligns with culturally sustaining pedagogy, ensuring students see their identities and heritage reflected in STEM while developing critical thinking skills. The study focuses on three core integrations: (1) Content (e.g., examining the medicinal compounds in traditional herbal remedies through chemistry), (2) Processes (e.g., applying scientific methods to study the efficacy of ancestral herbal knowledge), and (3) Tools (e.g., using modern instrumentation to analyze traditional preparation methods).

This study employs EthnoSTEM-based learning tools defined as culturally responsive educational instruments designed to bridge indigenous knowledge systems with formal STEM disciplines through contextualized materials, activities, and assessments. These tools operationalize EthnoSTEM pedagogy by transforming cultural practices into authentic STEM learning experiences. For example, traditional jamu-making processes are adapted into laboratory modules where students analyze phytochemical compounds using spectrophotometry while comparing results with ancestral knowledge of herbal efficacy. Unlike conventional STEM resources, EthnoSTEM-based tools prioritize cultural relevance by design such as using modern and traditional tools for traditional jamu production to teach physics principles or developing document medicinal plant biodiversity through local classification systems.

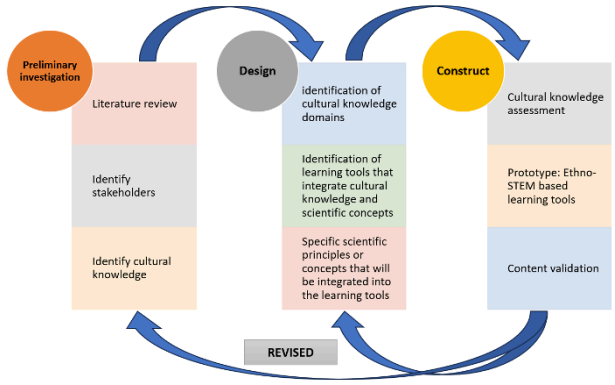
Method

This research uses Educational Design Research (EDR) by Bakker (2014), in which the research design is classified as development research, because it is related to the development of learning materials and resource. In this activity, the research design is used as follows 1) preliminary investigation; 2) design of EthnoSTEM-based learning tools; and 3) construction. At the preliminary investigation stage, a literature review is conducted as one of the initial steps. The design activity includes stage identification of cultural knowledge domains. Based on the identified cultural knowledge domains, EthnoSTEM-based learning tools that integrate cultural knowledge and scientific concepts were developed. These tools could include interactive multimedia resources, hands-on activities, and virtual simulations that contextualize scientific principles within the cultural contexts.

Independent variable is scientific concepts. This variable refers to the specific scientific principles or concepts that will be integrated into the learning tools. Examples of scientific concepts could include ecological systems, biological processes, chemical reactions. Dependent variable is feasibility of learning tools in integrating cultural knowledge and scientific concepts. This variable measures the degree to which the developed learning tools are successful in integrating cultural knowledge and scientific concepts. To develop EthnoSTEM-based learning tools that bridge cultural and scientific knowledge, researchers can utilize a range of instruments. Here are some instruments that can be used during the development phase: 1) Cultural knowledge assessment: A survey or interview-based instrument can be used to assess the cultural knowledge domains that exist within a particular community or cultural group. This will help identify the specific cultural knowledge areas to integrate into the learning tools; and 2) Content validation: Experts in both cultural knowledge and scientific concepts can be invited to review and validate the content of the learning tools. They can provide feedback on the accuracy and appropriateness of the materials to ensure that both cultural and scientific aspects are adequately represented.

To gather data for developing EthnoSTEM-based learning tools and bridging cultural and scientific knowledge, these steps can be considered: 1) conduct literature review; 2) identify stakeholders; 3) conduct interviews or focus groups discussion; 4) analyze data; 5) prototype and test: and 6) refine and improve the learning tools. Once the data is collected, it needs to be analyzed to identify patterns, themes, and key findings. This can involve coding qualitative data, conducting statistical analyses for quantitative data, and synthesizing the information gathered from different sources. This study involved 50 undergraduate student participants enrolled in the Science Education Program at a university in Yogyakarta, Indonesia. These participants were purposively selected based on the criteria of academic background, all were pre-service science teachers (majoring in Biology, Chemistry, or Physics education) with completed coursework in pedagogy and STEM disciplines. The stages of developing EthnoSTEM based learning tools as shown in Figure 1.

Figure 1.
Stages of developing product



The figure 1 outlines a systematic process for developing Ethno-STEM based learning tools, divided into three main phases: Preliminary Investigation, Design, and Construct. Here's a detailed explanation of each phase and its components: Preliminary investigation - the literature review was conducted by analyzing various sources of studies on ethnoscience, STEM, and various examples of local wisdom, one of which is traditional herbal medicine (jamu). Based on the results of the literature review, theoretical data were obtained for designing the product. Furthermore, indigenous and scientific knowledge were outlined as the initial identification. Identifying stakeholders in a project or initiative is a crucial step for ensuring its success, as stakeholders are individuals or groups that have an interest on or are affected by the project's outcomes. The project involves educators, students, and experts in both cultural and scientific fields to promote interdisciplinary collaboration. By identifying and engaging these stakeholders, the project can benefit from a wide range of perspectives and expertise, ensuring that the educational initiatives are comprehensive, inclusive, and effective. Cultural knowledge can be thoroughly identified and used for various purposes, both for cultural preservation and sustainable development. Identifying cultural knowledge involves understanding, gathering, and documenting various aspects of a particular culture that hold significant knowledge value. This process encompasses several key steps like data collection, categorization and validation of knowledge.

Design - In this phase, the focus is on integrating cultural knowledge with scientific principles to develop effective learning tools. Identification of cultural knowledge domains specify the areas of cultural knowledge that will be incorporated into the learning tools, such as traditional medicine, agricultural practices, or local technologies. Identification of learning tools integrates cultural knowledge and scientific concepts through developing and outlining learning tools that effectively combine cultural knowledge with scientific concepts to create a cohesive learning experience. The key scientific principles or concepts to be conveyed through these learning tools should be clearly identified and aligned with both cultural knowledge and STEM learning goals. .

Construct - This phase involves the practical implementation and validation of the designed learning tools by arranged cultural knowledge assessment to evaluate the accuracy and relevance of the cultural knowledge integrated into the learning tools, ensuring it is authentic and respectful of the culture. Develop prototypes of learning tools based on the identified cultural knowledge and scientific principles. Then, conduct content validation by testing the tools and gathering feedback from stakeholders, including educators, students, and cultural experts. . There is a feedback loop that indicates continuous revision and improvement throughout the process. Insights and feedback gathered during the construct phase are used to refine and enhance the preliminary investigation and design phases, ensuring the learning tools are effective and culturally appropriate.

Results

The results of a cultural knowledge assessment conducted through a survey or interview-based instrument would provide valuable insights into the cultural knowledge domains that exist within a specific community or cultural group. Some potential results that could be obtained include: Identification of cultural practices: 1) The assessment could reveal specific cultural practices, rituals, traditions, or customs that are important to the community or cultural group being studied. This could include knowledge of traditional ceremonies, traditional festivals, food preparation, storytelling, or artistic expressions. In this research, cultural knowledge results were obtained, including the use of spices for medicine, a beverage called "beras kencur", "kunir asem", a drink with special ginger and lemongrass ingredients, and traditional herbal manufacturing process. According to Bank (1998) herbal medicine is a prime example of indigenous knowledge that has significantly impacted people word wide. Highlight the importance of traditional knowledge and skills in supporting local learning contexts. . The assessment could uncover traditional knowledge and skills that have been passed down through generations within the community. In this research, we selected herbal medicine as the topic for learning tools. Results of activities at the first stage to gather data for developing EthnoSTEM-based learning tools and bridging cultural and scientific knowledge presented in the following table 1.

The process starts with conducting a thorough literature review on existing research, studies, and resources related to the intersection of culture and science in education. . Data were obtained information

about EthnoSTEM, cultural knowledge, and scientific knowledge. Identify the key stakeholders who will be involved in the development and implementation of the learning tools. This may include educators, students and experts in both cultural and scientific fields. Interviews or focus groups can be conducted with relevant stakeholders to gather more in-depth information. These sessions can provide a platform for participants to share their experiences, challenges, and suggestions for integrating cultural and scientific knowledge in education. The results of EthnoSTEM analysis on herbal medicine are presented in the following table 2.

In this phase, data are collected through surveys, questionnaires, interviews, or focus group and then analyzed systematically. Common themes, patterns, and insights are identified to inform the development of the learning tools. Based on the collected data and input from expert, prototypes of the EthnoSTEM-based learning tools are developed. These prototypes are tested in educational settings to evaluate their effectiveness, engagement, and cultural relevance. Feedback is gathered from teachers, students, and other users throughout this process. The feedback obtained during the testing phase is used to refine and improve the learning tools. This iterative process continues until the tools are effective, culturally sensitive, and aligned with both scientific and cultural knowledge. In the second phase, the primary focus is paced on integrating cultural knowledge with csientific principles to develop efective and contextually relevant learning tools.

The design stage successfully produced culturally integrated learning tools that align with scientific principles and support STEM education. Through the identification of relevant cultural knowledge domains, such as traditional medicine (jamu), local agricultural methods, and indigenous technologies, the content was made more relatable and contextually meaningful for learners. The integration of this cultural knowledge with scientific concepts led to the development of learning tools that promote a holistic understanding of STEM subjects.

Table 1.

Activities at the preliminary investigation

Stage	Step	Main Activity
Preliminary Investigation	Literature review	Analyzed various studies on ethnoscience, STEM, and examples of local wisdom, such as traditional herbal medicine (jamu). Findings provided theoretical data for product design.
	Stakeholders identification	Identified stakeholders such as educators, students, and experts in cultural and scientific fields. Engaging these groups ensures diverse perspectives and expertise for the project.
	Cultural knowledge identification	Involves understanding, gathering, and documenting valuable cultural aspects for preservation and sustainable development
	Indigenous and scientific knowledge	Identified as key elements in the initial stages of the investigation, combining both cultural and scientific perspectives.
	Data collection and validation	Process of collecting, categorizing, and validating knowledge to ensure accuracy and comprehensiveness in identifying cultural knowledge.

Tabel 2.

EthnoSTEM analysis on herbal medicine

No.	Component	Object
1.	Science	Herbal plants, secondary metabolite materials, mixture separation and additives.
2.	Technology	The utilization of tools in secondary metabolite extraction, use of technology in cultivating herbal plants, and packaging and distribution technology for herbal medicine (beras kencur and kunir asem).
3	Engineeriing	Herbal medicine manufacturing process, and waste processing process from herbal products.
4	Mathematics	The composition of ingredients in preparing traditional herbal remedies.

Table 3.

Activities at the design stage

Stage	Step	Main Activity
Design	Identification of cultural knowledge domains	Specific areas of cultural knowledge were selected for integration into learning tools. These included domains such as traditional medicine (e.g., jamu), agricultural practices, and local technologies.
	Development of integrated learning tools	Learning tools were designed to merge cultural knowledge with scientific concepts. These tools aim to provide learners with a holistic and relatable understanding of STEM topics.
	Alignment with scientific principles	Scientific principles relevant to the cultural domains were identified and incorporated into the learning tools. The goal is to ensure consistency with STEM objectives while maintaining cultural relevance.

Table 4.
Activities at the construct stage

Stage	Step	Main Activity
Construct	Cultural knowledge assessment	Conducted to evaluate the accuracy, authenticity, and cultural relevance of the knowledge integrated into the learning tools. This ensures the materials are respectful and true to the cultural context.
	Prototype development	Prototypes of the learning tools were created, based on the previously identified cultural knowledge and corresponding scientific principles. These prototypes serve as the foundation for practical application.
	Content validation	The content of the learning tools was validated through a series of testing and feedback sessions involving key stakeholders, including educators, students, and cultural experts.
	Feedback loop and continuous revision	Feedback collected during implementation was used to revise and improve earlier stages, including the preliminary investigation and design. This iterative process helps ensure effectiveness and cultural alignment.

The construct stage led to the development and refinement of culturally integrated learning tools through a systematic and collaborative process. The expert validation process yielded a mean score of 4.5 out of 5, indicating very high validity of the tool as perceived by the experts. The standard deviation of 0.3 reflects low variability, suggesting that the ratings were consistently high across evaluators. Scores ranged between 4.1 and 4.8, highlighting a strong consensus among experts regarding the quality and appropriateness of the tool. Notably, 90% of the scores were ≥ 4.3, further validating that the tool aligns well with EthnoSTEM principles and relevant pedagogical standards.

Cultural and Scientific Knowledge of Herbal Medicine

The cultural and scientific understanding of herbal medicine includes both traditional and contemporary approaches to using plants for health purposes. Many cultures have depended on herbal remedies passed down through generations. This traditional knowledge involves recognizing specific plants, creating remedies, and using them to treat or prevent various health issues. It is closely linked with local traditions, beliefs, and holistic practices that view the body, mind, and spirit as interconnected elements. On the scientific side, the study of herbal medicine according to the research by Sari et al. (2018) involves researching the chemical properties, pharmacological effects, and clinical efficacy of medicinal plants. Cultural knowledge of herbal medicine refers to the traditional understanding and practices related to using plants for healing and wellness within various societies. This knowledge is often passed down through generations and encompasses identifying medicinal plants, understanding their properties, and preparing and applying them for treating illnesses or promoting health. The analysis of 50 participants in terms of identification, classification, exploration, and construction of cultural and scientific knowledge is presented in Figure 2.

Figure 2.
An analysis of cultural knowledge and scientific knowledge

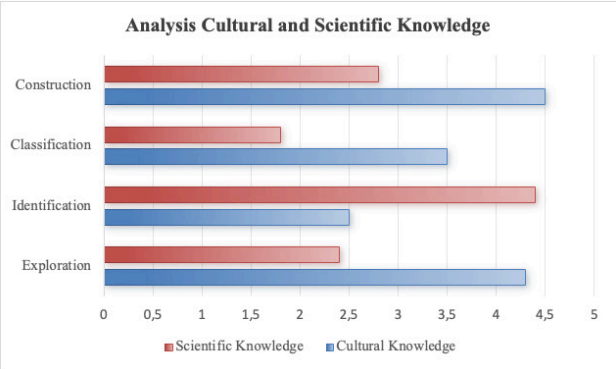


Figure 2 likely presents a visual representation of the results from the analysis of these aspects. The figure could include charts, graphs, or diagrams that show how the 50 participants performed in terms of identifying, classifying, exploring, and constructing both cultural and scientific knowledge. It may also illustrate the correlation or distinctions between the two types of knowledge and how participants navigated between cultural and scientific frameworks in their understanding. The percentage of participants' achievement in each aspect of cultural and scientific knowledge is presented in the table 5 below.

Table 5.
Percentage of participants' achievement in each aspect of cultural and scientific knowledge

Aspect	Cultural Knowledge	Scientific Knowledge
Exploration	88%	60%
Identification	60%	90%
Classification	76%	40%
Construction	94%	64%

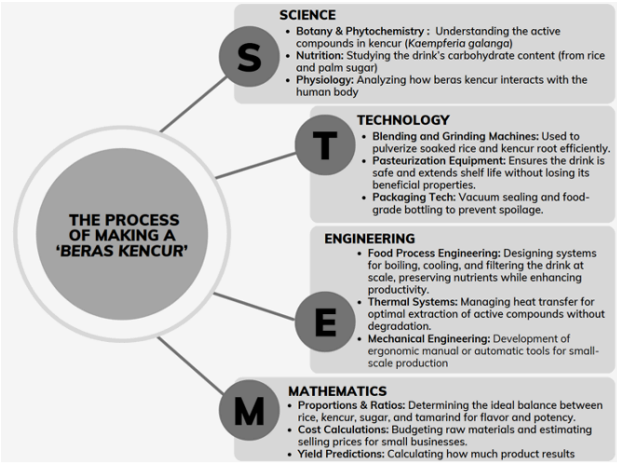
An analysis of cultural and scientific knowledge often involves understanding how these two aspects interact and influence each other in various contexts, such as social, environmental, and technological settings. Here's an overview of the results of analyzing these two domains: Cultural knowledge refers to the understanding of values, traditions, language, customs, and social norms passed down within a community or society. In a cultural analysis, the following aspects are often highlighted; exploration, identification, classification, and construction of 1) social values; 2) role of traditions and 3) intercultural interaction. Scientific knowledge pertains to the facts, theories, and principles derived through the scientific method, such as observation, experimentation, and data analysis. In an analysis of scientific knowledge,

the focus includes 1) scientific method 2) theories and discoveries; and 3) technological innovations.

The classification of cultural and scientific knowledge helps to differentiate between knowledge that is rooted in tradition, beliefs, and experiences versus knowledge that is systematically derived, tested, and validated through empirical methods. Exploring cultural and scientific knowledge involves examining how these two distinct bodies of knowledge are formed, transmitted, and applied in understanding the world. While cultural knowledge is deeply rooted in the customs, practices, and beliefs of a specific community, scientific knowledge is systematic, empirical, and universal. Despite their differences, there are significant overlaps, especially when both types of knowledge intersect in areas like ethnobotany, medicine, agriculture, and ecology.

Jamu is a traditional Indonesian herbal medicine made from natural ingredients such as roots, bark, flowers, seeds, leaves, and fruits. It is commonly used to maintain health, prevent illness, and treat various ailments. According to Estiasih et al. (2024), Jamu is usually prepared as a drink but can also be found in powder or capsule form. "beras kencur" is a traditional Indonesian herbal beverage, part of the jamu tradition, composed mainly of rice (beras) and aromatic ginger (kencur, Kaempferia galanga). This drink is renowned for its health benefits and cultural significance. Beras Kencur is prepared by soaking rice and combining it with ground aromatic ginger. The mixture is then boiled, cooled, and filtered to produce a sweet, slightly spicy beverage. The roasted rice contributes to the drink's viscosity and provides energy, while the aromatic ginger imparts a warm sensation and distinctive flavor. The example of the analysis of STEM components in the process of making a 'beras kencur' drink presented in figure 3.

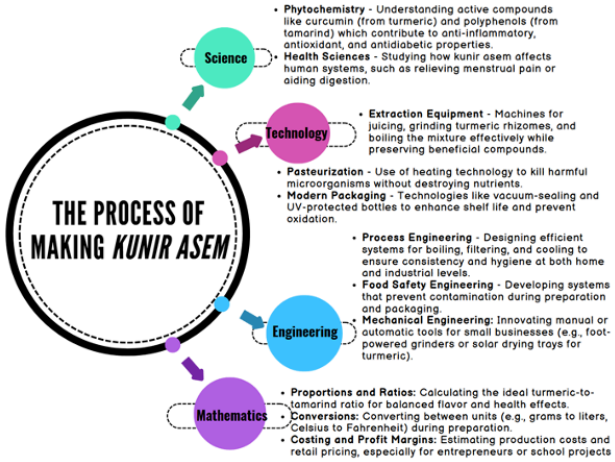
Figure 3.
The analysis of STEM components in the process of making a 'beras kencur' drink



Based on figure 3 the process of making beras kencur showcases the interplay of chemical, biological, and physical principles. Understanding these scientific processes enhances appreciation for this traditional drink and its health-promoting properties. The technology in the making of beras kencur ranges from traditional tools to advanced equipment that enhances production, packaging, and distribution. These innovations ensure that this traditional drink remains relevant, accessible, and enjoyable in modern times while retaining its cultural significance.

Engineering contributes significantly to the evolution of beras kencur production, from small-scale traditional methods to industrial-scale operations. By applying principles of mechanical, thermal, chemical, and systems engineering, the process becomes more efficient, sustainable, and adaptable to modern demands while preserving the essence of this traditional drink. Mathematics ensures precision and efficiency throughout the process of making beras kencur, from measuring ingredients to optimizing extraction and packaging. It bridges traditional practices with modern methods, enabling scalable and consistent production while preserving the drink's unique characteristics. Kurniawan et al. (2021) said that kunir asem, also known as turmeric-tamarind herbal drink, is a traditional Indonesian beverage made from turmeric (Curcuma domestica or Curcuma longa) and tamarind (Tamarindus indica). This drink is widely consumed for its health-promoting properties, particularly its antioxidant and anti-inflammatory effects. The analysis of STEM components in the process of making a 'kunir asem' drink presented in figure 4.

Figure 4.
The analysis of STEM components in the process of making a 'kunir asem' drink



The preparation of kunir asem integrates STEM components based on figure 4 seamlessly, blending traditional knowledge with modern advancements. Science explains the chemistry behind the drink,

technology and engineering refine its production and packaging processes, and mathematics ensures precision and scalability. This holistic integration underscores the value of STEM in preserving and innovating traditional culinary heritage.

Cultural practices in herbal medicine are deeply embedded in the beliefs, customs, and holistic views of different communities. They consider not only the physical aspects of healing but also the spiritual and emotional dimensions. For example, many traditional healers use rituals or specific practices that are believed to enhance the efficacy of herbal treatments by aligning the mind, body, and spirit. This type of knowledge is often tied to local biodiversity, with communities understanding which plants are effective based on their ecological surroundings. It reflects a profound connection with nature and an intuitive grasp of natural resources that has been refined over centuries. Cultural knowledge of herbal medicine preserves historical practices and highlights the value of natural, sustainable approaches to health and wellness.

According to Foss et al (2022), scientists analyze the active compounds in herbs to understand their mechanism of action and potential health benefits Building on this foundation, the present research not only validates Ethno-STEM learning tool practices but also support the integration of herbal medicine into mainstream healthcare by promoting safety standards, dosage guidelines, and evidence-based applications. The blend of cultural and scientific knowledge in herbal medicine enhances its credibility and effectiveness. While cultural perspectives based on Balkrishna et al. (2024) provide a rich historical context and holistic approach, scientific research ensures that herbal treatments are safe, consistent, and effective for broader use. This combination allows for the preservation of valuable traditional practices while advancing the field through modern innovation and scientific validation.

Discussion

The results of this research focus on the integration of traditional medicine as EthnoSTEM-based learning tools. According to WHO (2022) herbal medicine or traditional medicine is defined as a collection of knowledge and skills consisting of medical activities that adhere to original theories or beliefs that have developed in society from generation to generation, regardless of whether they are accepted or not. Traditional medicine according to Wilder (2000) is included in indigenous knowledge and was trusted by society before the advent of modern medicine. Jamu is traditional medicine, included in indigenous knowledge that has existed for a long time and has been passed down from generation to generation. According to the study by Sujatmiko (2021) conducted in Indonesia, herbal medicine is a hereditary heritage originating from medicinal plants such as ginger, ginger, lemongrass and so on, and the process of making them is characteristic. Jamu as a traditional medicine with indigenous knowledge, contains concepts that can be integrated into STEM education, through bridging ethoSTEM-based learning tools.

Cultural and Scientific Knowledge is an in-depth understanding of a society's cultural heritage and scientific advancements. This knowledge encompasses various aspects, including traditions, languages, arts, and customs that shape cultural identity, as well as discoveries, theories, and scientific innovations that drive human progress in numerous fields. Classroom practices in science education promote indigenous knowledge by fostering exploration. According to Devkota and Timilsena (2023), emphasis is placed on science lessons that recognize Indigenous perspectives and incorporate diverse knowledge systems. Cultural knowledge is essential in preserving ancestral heritage and fostering collective pride, helping individuals understand the values and norms within a community. Meanwhile Gondwe andLongnecker (2014) explain that scientific knowledge guides humanity toward a deeper comprehension of the universe, natural phenomena, and the principles governing daily life. With scientific insights, we can create technologies that improve quality of life, address global challenges, and expand our understanding of human existence. Galili (2021) stated that the combination of cultural and scientific knowledge forms a solid foundation for societies' holistic growth. Understanding both types of knowledge fosters tolerance and curiosity while encouraging responsible and sustainable innovation. Moreover, blending cultural and scientific insights allows communities to find new ways to solve problems creatively and inclusively.

The table 6 below provides a comparative overview of cultural knowledge and scientific knowledge in the context of traditional herbal medicine, specifically focusing on jamu, a traditional Indonesian herbal remedy. The comparison is organized into five key aspects: source, application, ingredients, preparation, and efficacy. This side-by-side analysis illustrates how cultural traditions and modern scientific approaches both contribute to the understanding, use, and development of jamu. While cultural knowledge emphasizes ancestral wisdom and community practices, scientific knowledge focuses on empirical validation, standardization, and research-based innovations.

EthnoSTEM approach

EthnoSTEM is an educational approach that integrates ethnoscience—traditional knowledge and cultural practices—with the disciplines of Science,

Technology, Engineering, and Mathematics (STEM). This methodology emphasizes the incorporation of local wisdom and cultural heritage into STEM education, aiming to make learning more contextual and relevant to students' lived experiences. By bridging indigenous knowledge systems with modern scientific concepts, EthnoSTEM seeks to enhance students' understanding and appreciation of both domains. One significant application of EthnoSTEM is in the development of educational modules that incorporate local cultural practices. For instance, a study conducted in Yogyakarta, Indonesia, developed an EthnoSTEM e-module based on local wisdom, utilizing a Project-Based Learning (PjBL) model. This approach aimed to improve students' creative thinking abilities by engaging them in projects rooted in their cultural context, such as traditional crafts and local technologies. The study by Ariyatun (2021) found that this method was effective in enhancing students' engagement and creativity in science learning.

According to Feille and Wildes (2021), the implementation of authentic engineering practices in elementary school education can increase students' interest in STEM careers and boost their confidence in future engineering studies. Furthermore, integrating EthnoSTEM with project-based learning has been shown to positively impact students' critical and creative thinking skills. Research involving high school students demonstrated that EthnoSTEM-based projects, which incorporated local cultural elements, led to significant improvements in these cognitive skills. The students engaged in projects that required them to apply scientific concepts to culturally relevant problems, thereby fostering a deeper understanding and appreciation of both their cultural heritage and scientific principles. An alternative way to design science learning activities using the ethnoSTEM approach is presented in the following table 7.

The EthnoSTEM approach also addresses the need for culturally responsive teaching materials that resonate with students' backgrounds. According to Izzah et al. (2023), by integrating local wisdom into STEM education, educators can create learning experiences that are more meaningful and engaging for students. This method not only enhances conceptual understanding but also promotes positive attitudes towards science and technology, as students see the relevance of these subjects in their own cultural contexts. EthnoSTEM represents a pedagogical strategy that combines traditional cultural knowledge with STEM education to create a more holistic and engaging learning experience. According to Marufi et al. (2021) and Babalola and Keku, (2024) contextualizing scientific concepts within students' cultural frameworks, EthnoSTEM fosters critical and creative thinking, enhances conceptual understanding, and promotes a greater appreciation for both indigenous knowledge and modern science. This approach has been effectively implemented in various educational settings, demonstrating its

Table. 6

Comparison of Cultural Knowledge and Scientific Knowledge in Traditional Herbal Medicine

Aspects	Cultural knowledge	Scientific kowledge
Source	Knowledge of jamu is typically passed down orally through generations within families or communities.	Scientific knowledge about jamu is documented in research papers, journals, and books.
Application	The use of jamu is deeply rooted in cultural practices, rituals, and beliefs, making it an integral part of the community's way of life.	Scientific studies of jamu focus on understanding the biochemical properties and mechanisms of action of its ingredients.
Ingredients	Jamu uses natural ingredients a variety of locally sourced plants, herbs, roots, and spices	Scientific research aims to standardize the active compounds and ensure consistent quality and potency.
Preparation	Traditional Techniques preparation methods include grinding, boiling, and mixing, with recipes varying by region and practitioner.	Preparation methods are often refined and controlled using modern laboratory techniques to maximize efficacy and safety.
Efficacy	The effectiveness of jamu is often supported by anecdotal evidence and the collective experience of the community. Some formulations are believed to have spiritual or magical properties, influencing their perceived efficacy.	The effectiveness of jamu is validated through empirical evidence obtained from laboratory tests and clinical trials. Research identifies active compounds, their pharmacological effects, and potential side effects, providing a scientific basis for their use.

Table 7.

An alternative design science learning activities using the ethnoSTEM

Ethno-based project theme	Classroom activities with STEM components			
	Science	Technology	Engineering	Mathematics
Preparing a traditional herbal drink (beras kencur)	Extract essential oils and test antioxidant levels	Compare traditional vs modern equipment	Design a simple production system	Calculate nutritional values and profit margins
Production of a traditional herbal beverage (kunir asem)	Extract and analyze curcumin content using UV light or simple chromatography	Compare traditional and electric juicers for turmeric	Build a solar-powered drying rack for turmeric rhizomes	Calculate antioxidant levels or sugar content based on mass-volume ratios

potential to enrich STEM education through cultural integration.

This EthnoSTEM approach exemplifies how STEM education can be transformed into a culturally responsive and socially relevant discipline. By centering traditional knowledge systems like jamu-making as legitimate scientific discourse, we challenge the artificial dichotomy between "modern" science and Indigenous wisdom. The jamu case study specifically demonstrates three key connections: 1) Conceptual - where phytochemical analysis of turmeric (Curcuma longa) in jamu validates its anti-inflammatory properties through both Western biochemistry and Javanese empirical knowledge; 2) Methodological - documenting the engineering precision of traditional stone mortar (cobek) techniques that optimize bioactive compound extraction; and 3) Pedagogical - developing lesson plans where students compare laboratory distillation methods with ancestral jamu decoction practices.

The Impact of EthnoSTEM-based learning tools

Learning tools based on Ethno-STEM, which integrate ethnic knowledge with science, technology, engineering, and mathematics, have a notable effect on education. These tools help build a more inclusive educational atmosphere by recognizing and integrating the cultural backgrounds of students. This method can enhance student engagement and motivation by making learning more relatable to their personal experiences and cultural heritage. The impact of using ethno-STEM learning tools includes fostering a deeper understanding of STEM concepts by linking them to real-world, culturally relevant examples. In line with the research conducted by Nessa et al. (2017) and Riyadi et al. (2018), this connection helps students see the practical applications of STEM in their communities and everyday lives, enhancing both comprehension and retention. Additionally, these tools promote critical thinking and problem-solving by encouraging students to approach scientific and technical problems from diverse perspectives.

Moreover, ethno-STEM learning fosters respect for indigenous knowledge and practices, highlighting the value of traditional wisdom alongside modern scientific thought. This dual perspective not only preserves cultural heritage but also encourages innovation by blending time-tested methods with contemporary STEM strategies. Ultimately, according to Listiyani (2018) and Ardwiyanti et al, (2021) the integration of ethno-STEM tools can support a more holistic, culturally responsive, and effective education system. EthnoSTEM-based learning tools acknowledge and promote the cultural identities and provide experiences of diverse student community. By integrating students' cultural backgrounds and traditions into the curriculum, these tools enhance cultural relevance, making the learning experience more meaningful and engaging for students. Research by Akker et al. (2010) indicates that when students see themselves reflected in the content and instructional methods, they feel a stronger sense of ownership and connection to the learning process. EthnoSTEM-based learning tools, by incorporating culturally relevant examples and contexts, can increase student engagement and motivation in STEM subjects.

EthnoSTEM-based tools use cultural contexts to make abstract scientific concepts more relatable. For example, studying traditional herbal medicine can introduce students to topics like botany, chemistry (extraction of active compounds), and biology (plant anatomy and functions). Cultural practices, such as batik-making, can be used to teach the chemistry of dyes, temperature effects, and diffusion. By grounding science lessons in familiar cultural activities, students develop a stronger connection to the subject matter. These tools encourage students to explore science as part of a broader system interconnected with technology, engineering, and mathematics. This interdisciplinary approach enhances critical thinking and problem-solving skills. Learning tools rooted in EthnoSTEM make lessons more engaging and memorable by leveraging hands-on, project-based activities that reflect students' cultural heritage, such as building traditional windmills or solar cookers. Sudarmin et al (2020) and Sasmita et al (2024) emphasize the importence of encouraging inquiry-based learning, in which students actively investigate the scientific principles embedded within cultural practices to deepen their scientific understanding. . These activities not only make science enjoyable but also deepen understanding and retention of key concepts. Chashike et al. (2025) explain that students learn how traditional ecological practices, such as crop rotation or herbal remedies, align with modern scientific principles like sustainability and biodiversity. By integrating this knowledge, students see their cultural heritage as a source of scientific insight rather than as separate or outdated. This fosters a sense of pride and responsibility toward preserving cultural traditions.

The relationship between cultural knowledge and scientific knowledge in the context of herbal medicine is a complex and dynamic interaction. Herbal medicine, which involves the use of plants and plant-based compounds for therapeutic purposes, has been practiced for centuries across different cultures. Over time, scientific research has both supported and expanded upon many traditional practices, while culture continues to influence how herbal remedies are used, understood, and accepted in modern society. EthnoSTEM-based learning tools have the potential to address educational disparities among different ethnic and cultural groups. Based on

the research conducted by Wulandari and Wulandari (2016) and Wulandari and Azrianingsih (2014) recognizing and valuing diverse cultural perspectives, these tools create an inclusive learning environment that respects students' cultural backgrounds and provides equal opportunities for success in STEM fields. Abonyi et al. (2014) argue that these tools often involve problem-solving activities that draw on real-life situations or challenges faced by different cultural communities. This approach not only strengthens students' critical thinking and problem-solving skills but also prepares them to address real-world issues from diverse perspectives, fostering cultural competence.

Based on previous research by Sumarni and Kadarwati (2020), EthnoSTEM-based learning tools can also be collaborated with learning models and have an impact on improving students' cognitive abilities. Rinto et al. (2022) maintain that combining or collaborating EthnoSTEM learning tools with project based learning models leads an increase in students' critical and creative thinking skills. This increase is due to collaborating EthnoSTEM-based learning tools with project based learning which can help students understand scientific concepts and their relationship with technology, engineering and mathematics. Apart from that, students are trained to think flexibly, original, critically and creatively in carrying out experimental activities, making projects and presentation projects. According to Acar et al. (2018), STEM training improves students' achievement in science and mathematics, fosters positive attitudes toward the training, encourages interest in future participation, and motivates students to consider careers in STEM fields. Griffiths's et al (2020) support this study by emphasizing that the growth of job opportunities and technological advancements necessitates increased diversity within the labor market. . All students require innovative early training to successfully pursue careers in the STEM fields.

Incorporating indigenous knowledge in STEM learning can be a representation of various cultural backgrounds. Apart from that, according to De Beer and Whitlock (2009) and Botha (2012) it can also improve the interpretation of scientific knowledge in this STEM context, so that EthnoSTEM-based learning tools can be relevant if applied in classes with students who have diverse backgrounds. As explained by Sumarni et al. (2020), students will more easily understand scientific knowledge through EthnoSTEM-based learning tools. Studies Andayani & Anwar (2023) have found that culturally responsive pedagogy positively impacts student achievement in STEM subjects. EthnoSTEM-based learning tools, through their emphasis on cultural relevance and inclusivity, can contribute to improved academic outcomes and narrow achievement gaps among diverse student populations.

The benefits of EthnoSTEM-based learning tools are not only felt by students, but also by teachers. According to Rahayu and Sudarmin (2015) and Nessa et al. (2017) EthnoSTEM tools aim to bridge the gap between indigenous knowledge systems and scientific knowledge. Karalar et al., (2021) explained that STEM activities help students understand that scientific knowledge and cultural practices are not separate but can complement and enrich each other. Through EthnoSTEM-based learning tools, teachers will be able to further explore indigenous knowledge that develops in society and is integrated with STEM education. It is important to note, as stated by Bramastia (2023), that while there is growing evidence supporting the benefits of EthnoSTEM-based learning tools within the framework of culturally responsive pedagogy, further research and implementation in diverse educational settings are necessary to fully validate this theory.

EthnoSTEM-based learning tools are powerful resources for science education, connecting cultural knowledge with scientific concepts to create a rich, meaningful learning experience. By contextualizing lessons, promoting interdisciplinary approaches, and fostering appreciation for local traditions, these tools prepare students to become globally aware yet culturally grounded scientists, innovators, and problem solvers. They represent an essential step toward creating inclusive, sustainable, and relevant educational systems for the future.

Conclusion

Developing EthnoSTEM-based learning tools is an essential step towards bridging cultural and scientific knowledge. This approach recognizes the unique ways in which different cultures understand and interact with science, technology, engineering, and mathematics (STEM). By incorporating cultural perspectives and traditional knowledge into STEM education, we create a more inclusive and diverse learning environment. EthnoSTEM serves both as an educational strategy and a cultural preservation tool. Unlike traditional STEM education, which often separates scientific concepts from students' lived experiences, EthnoSTEM connects learners to their roots, demonstrating the relevance of scientific thinking within their own cultural contexts. EthnoSTEM learning tools encourage students to explore their own cultural heritage and understand how it intersects with scientific principles.

EthnoSTEM-based learning empowers students to appreciate and preserve their cultural heritage while equipping them with the scientific and technological literacy needed to navigate modern challenges. It fosters inclusivity by validating diverse cultural perspectives and promotes sustainability by emphasizing local knowledge systems. Furthermore,

this integration encourages interdisciplinary learning, where students see the relevance of STEM concepts in real-world and culturally meaningful contexts. EthnoSTEM provides a pathway to create culturally relevant curricula that resonate with diverse learners. Future efforts should focus on refining these tools through research, collaboration with cultural practitioners, and iterative feedback from educators and students. This will ensure that EthnoSTEM continues to serve as a bridge between the past and the future, inspiring learners to value their cultural roots while embracing scientific innovation.

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The Science Coaster: A Virtual Reality Journey in Science Education

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Abstract

This study was designed to examine how the science teaching process was conducted using Science Coaster, a virtual reality application developed for fourth-grade primary school students, and to identify the effects of this process on students' academic achievement, motivation, and experiences. The research was structured as a case study, and the participants consisted of 33 fourth-grade students and their classroom teachers. Data collection tools included an observation form, researcher diary, student diary, interview form, academic achievement test, and a motivation scale for science learning. The Science Coaster virtual reality software was specifically developed by the researchers for the unit "Earth's Crust and Movements of Our Planet" in the science curriculum. The implementation process was conducted individually, and students interacted with the content using a virtual reality headset and controller. The findings revealed that the Science Coaster-based instructional process could be successfully implemented in three main phases: lesson preparation, implementation, and assessment-evaluation. Quantitative results indicated a statistically significant increase in students' academic achievement in science and improvements in all sub-dimensions of their motivation. Qualitative data supported these findings, showing that students perceived the virtual reality experience as enjoyable, instructive, immersive, realistic, and motivating. During the research process, specific technical-physical issues and student-experience-based limitations were encountered; however, various solutions were implemented to address these challenges. The findings suggest that virtual reality technology holds pedagogical potential in science education and can be used as an effective instructional tool, particularly at the primary school level.

Keywords:

Primary Science Teaching, Virtual Reality, Technology In Science Teaching.

Introduction

The digital dimension of the 21st century, driven by rapid technological advancements, is fundamentally transforming individuals' lifestyles and ways of accessing information. Today's students are frequently referred to as "digital natives"; this generation comprises individuals who are innately familiar with online platforms, capable of multitasking, and prefer learning in interactive environments (Bilgiç et al., 2011). The learning styles of this digital generation necessitate instructional approaches that go beyond

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traditional teaching methods and actively integrate technology into the learning process. In this context, technology's practical and meaningful use in education is becoming increasingly significant. Particularly, technology-enhanced instructional materials have been shown to increase students' motivation toward learning, direct their attention to the lesson, and support the retention of acquired knowledge (İşman et al., 2002). Integrating technology into instruction transforms the learning environment from a process based solely on transmitting knowledge into one that is experiential, student-centered, and interactive. At this point, science education emerges as one of the disciplines most receptive to the opportunities offered by technology. With its fundamental goals of understanding natural phenomena, conducting experimental processes, and concretizing abstract concepts, the science curriculum benefits from multidimensional visualization, animation, and simulation techniques (Rutten et al., 2012; Smetana & Bell, 2012; Wang et al., 2010). However, the limitations of conventional classroom settings often hinder realizing this potential, making integrating new technologies into instruction inevitable. In particular, abstract content that students are unable to observe or experience firsthand cannot be effectively taught due to constraints related to safety, time, and space (Arıcı, 2013; Hacıeminoğlu, 2019).

In recent years, virtual reality has emerged as one of the technologies capable of addressing these educational needs. Virtual reality refers to computer-generated environments that provide users with a sense of realism while enabling interactive engagement within a three-dimensional space. This technology activates not only users' visual senses but also auditory, tactile, and spatial perceptions, thereby creating a strong sense of "being there" and transforming learning into a multisensory, experiential process (Bayraktar&Kaleli, 2007; Çavaş et al., 2004). The use of virtual reality in education is examined within the context of immersive interfaces that significantly influence learners' cognitive and affective processes. Such environments are suggested to enhance students' attention, deepen information processing, and increase learning motivation (Dede, 2009). Moreover, virtual reality is reported to support the development of empathy, foster social awareness, and enable the experiential construction of abstract concepts, thereby contributing to transformative learning processes (Bailenson, 2018). Research on the use of virtual reality in education has shown that students exhibit higher levels of motivation in science courses where this technology is employed, develop more positive attitudes toward scientific content, and achieve greater academic success (Liang et al., 2025; Liu et al., 2022; Villena Taranilla et al., 2019; Yang et al., 2021). Furthermore, it has been emphasized that students experience significant gains in conceptual understanding, higher-order thinking skills, and visual-spatial abilities (Sulisworo et al., 2022). However, virtual reality-based science education studies conducted at the primary school level remain limited in number, with most existing research focusing on secondary and higher education (Jensen, & Konradsen, 2018; Merchant et al., 2014). This highlights the need for a more in-depth examination of the implementation processes, educational impacts, and classroom integration strategies of virtual reality applications targeting young learners in primary education.

Primary school students are typically in the concrete operational stage, defined by Piaget's theory of cognitive development, and often face challenges in mentally constructing abstract concepts. Therefore, visualization and experiential learning are important in helping students grasp geological, astronomical, or microscopic-scale concepts essential in science education (Lester et al., 2014). Virtual reality technology offers an environment that directly addresses this need by allowing students to explore at their own pace, focus their attention on content, and actively participate in the learning process. One of the key theoretical frameworks supporting the educational use of virtual reality is Richard E. Mayer's Cognitive Theory of Multimedia Learning. According to this theory, individuals process and learn information more effectively when multiple sensory channels are engaged simultaneously. In particular, the combination of visual elements (images, animations, videos) with auditory elements (narration, sound, music) enhances learning quality and contributes to more effective mental organization during the learning process (Mayer, 2001; 2009). Grounded in cognitive load theory, Mayer's model argues that multimedia materials should be designed according to specific principles to enable more efficient use of learners' limited working memory. These principles include coherence (eliminating extraneous information), signaling (highlighting essential content), redundancy (limiting simultaneous written and spoken explanations), personalization (using conversational rather than formal language), and temporal/spatial contiguity (presenting related visuals and texts together). Multimedia content developed in line with this theory supports meaningful learning by optimizing students' processes of selecting, organizing, and integrating information (Mayer, 2009).

This theoretical approach is exceptionally functional in explaining the impact of multisensory and interactive environments, such as virtual reality, on learning. Virtual reality applications enrich the learning environment through multiple forms of representation by simultaneously presenting visual, auditory, and kinesthetic content, thereby enabling students to establish a deeper cognitive connection with the material. Moreover, this technology allows students to actively participate in the learning environment, take control of their learning process,

and become more highly motivated to engage with the content (Kavanagh et al., 2017). In this context, it is important to evaluate virtual reality-based instructional practices designed for primary school students from both pedagogical and technological perspectives to understand their effects on children's cognitive and affective development. While most studies in virtual reality-supported science education focus on secondary and high school levels (Jensen, & Konradsen, 2018; Merchant et al., 2014; Şevgin, 2024), the present study addresses a systematically implemented instructional process at the primary school level.

This study examines how the virtual reality-based science instruction process, developed for fourth-grade primary school students, is implemented. In line with this aim, the study's main research question is: "How can a virtual reality-based science instruction process developed for fourth-grade primary school students be implemented?" Within this scope, the sub-questions of the research are as follows:

- How is the virtual reality-based instructional process conducted in the fourth-grade primary school science course?
- How does the academic achievement of fourth-grade primary school students change in a virtual reality-based science course?
- How does the motivation level of fourth-grade primary school students change in a virtual reality-based science course?
- What are the views of fourth-grade primary school students and their classroom teachers regarding the virtual reality-based science course?
- What problems are encountered during the implementation of the virtual reality-based science course in the fourth grade of primary school?
- How can the problems encountered during the implementation of the virtual reality-based science course in the fourth grade of primary school be addressed?

This study provides original data on how virtual reality applications can be structured at the primary school level and how they can be functionally utilized in science instruction. Considering that technology integration in education represents not merely an instrumental transformation but also a pedagogical paradigm shift, the instructional model presented in this study serves as a valuable resource for teachers, curriculum developers, and researchers. Furthermore, it contributes to ongoing efforts to develop alternative methods to enhance students' motivation and conceptual understanding in the science learning process.

Method

Research Design

This study explores how the science instruction process, based on a virtual reality application developed for fourth-grade primary school students, is implemented. A qualitative research approach was adopted, and the study was designed as a case study. Case study design is particularly preferred when seeking answers to "how" and "why" questions, especially in situations where the researcher has limited control over events and the focus is on a phenomenon within its real-life context (Yin, 2014). In this context, the study was conducted within the framework of a holistic single-case design, in which a single phenomenon (the instructional process) was examined comprehensively.

Study Group

The study group consisted of 33 fourth-grade students (19 boys and 14 girls) enrolled in a public primary school with a middle socio-economic profile and two classroom teachers. First, schools were identified, and following classroom observations and interviews with teachers, the study group was selected. Participants were chosen using criterion sampling, a purposeful sampling technique. Criteria such as physical facilities, voluntary participation, and location were considered when selecting the school for the research. As for the students, the criteria included high attendance in class, voluntary participation, absence of intellectual disabilities, and parental consent. To ensure confidentiality in presenting findings, each participant was assigned a pseudonym.

Development of the Virtual Reality Software

The instructional process at the center of this study was based on a newly developed virtual reality (VR) application—Science Coaster—which was explicitly designed in alignment with the learning outcomes of the science unit "The Earth's Crust and the Movements of Our Planet." This application was developed for the first time and tailored to the designated instructional content. The ADDIE instructional design model guided the design process, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. In the analysis phase, abstract and difficult-to-observe concepts that students typically struggle with were identified, leading to the selection of the unit "The Earth's Crust and the Movements of Our Planet." The need for concretization in science topics was addressed through the three-dimensional modeling and interactive environments afforded by virtual reality technology. During the design phase, scenario development was carried out, and the content was revised based on feedback from six experts and three classroom teachers. All content and voiceovers were structured to be appropriate for the

primary school level and aligned with the cognitive objectives of the unit. In the development phase, Unity software was used to create 3D environments (surface, underground, space, solar system); animations, roller coaster mechanics, voiceovers, and user interaction systems were also integrated. In the Science Coaster application, the student navigates through various environments via a VR headset, listens to narrated explanations, and responds to questions using buttons on the controller. During the implementation phase, a pilot study was conducted to observe student behaviors, and necessary adjustments were made to the content. In the evaluation phase, data collected from students, teachers, and researchers were examined collectively; elements that caused distraction or operational difficulty were revised, and user interaction was improved.

In addition, the design of the Science Coaster virtual reality application was grounded in the Cognitive Theory of Multimedia Learning, and the application was developed based on the twelve core principles proposed by Mayer (2009). The content, audio, and visuals were structured following the principles of Coherence, Signaling, Redundancy, Temporal and Spatial Contiguity, Segmenting, Pre-training, Modality, Multimedia Principle, Personalization, Voice, and Image. To direct students' attention, narrated explanations were synchronized with visuals, and extraneous content was avoided. With its interactive structure, Science Coaster supports meaningful and lasting learning by enabling students to simultaneously engage their visual and auditory channels. The application's language was personalized to be simple, level-appropriate, and guiding for primary school students. After the completion of all ADDIE phases, the final version of the program was produced. An example screenshot from the surface section of the three-dimensional environments is presented in Figure 1, and an example from the space section is shown in Figure 2. By scanning the QR code provided in Figure 3, the first video segment of the Science Coaster application can be accessed, while the QR code in Figure 4 links to the second segment.

Figure 1.
A screenshot from the first section of the Science Coaster application

Figure 2.
A screenshot from the second section of the Science Coaster application

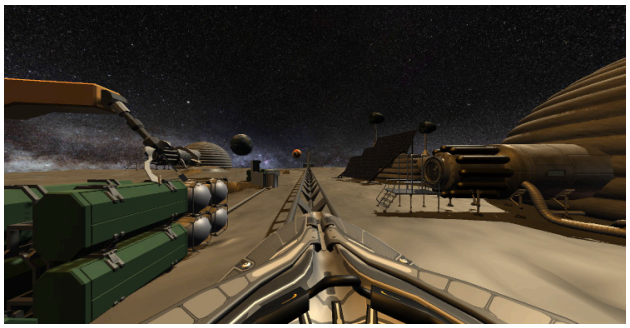


Figure 3.
QR code for accessing the video of the first section of the Science Coaster application

Figure 4.
QR code for accessing the video of the second section of the Science Coaster application

Implementation Process

The program was implemented individually. Due to pandemic conditions, students participated in the application one at a time, interacting with the VR equipment and experiencing the content. Two students participated each day, and the implementation lasted six weeks. The sessions were conducted in the school library, each recorded on video. During the implementation, students' reactions to the content, interactions, and engagement throughout the process were observed in detail.

Data Collection Tools

Achievement Test for the Science Unit "The Earth's Crust and the Movements of Our Planet"

The achievement test, developed by the researcher for fourth-grade primary school students, consists of 30 items and is a measurement tool whose validity and reliability have been analyzed. The test development followed the steps proposed by Adıgüzel (2016), and the questions were prepared based on Bloom's taxonomy. Initially, 45 questions were created to address the five learning outcomes of the unit. These 45 items and a specification table were sent to eight experts for review—four experts in science education, one in Turkish language education, one in educational measurement and evaluation, and two classroom teachers. The Content Validity Ratios (CVRs) and the Content Validity Index (CVI) were calculated based on expert feedback. As a result of this evaluation, 10 questions were removed. CVR values ranged between 0.50 and 1.00 for the remaining items, and the CVI was calculated as 0.85. The test was administered to 196 fourth-grade students as part of a pilot study. Following the pilot, item discrimination and difficulty indices were computed. Based on the item analysis, five items were excluded from the test. The discrimination indices for the remaining items were all above 0.20 (Pande et al., 2013), and the difficulty indices ranged between 0.48 and 0.79, with an average difficulty index of 0.70 (Özçelik, 1998). The reliability of the test was calculated using the KR-20 formula, and the reliability coefficient was found to be 0.75. This value indicates that the test scores are highly reliable (Özdamar, 2017). All validity and reliability analyses conducted confirm that the developed achievement test is a valid and reliable measurement tool. The minimum possible score on the test is 0, and the maximum is 30.

Motivation Scale for Science Learning

The scale was initially developed by Tuan et al. (2005) to measure elementary school students' motivation toward science learning and was adapted into Turkish by Yılmaz and Huyugüzel Çavaş (2007). The scale consists of a total of 33 items grouped under six factors. During the Turkish adaptation process, expert opinions were collected from nine faculty members specialized in science education, educational measurement and evaluation, and foreign languages. Following a pilot study, an Exploratory Factor Analysis [EFA] was conducted, and two items were removed from the scale. The factor analysis results revealed a six-factor structure consistent with the original version of the scale. These six factors were labeled as: self-efficacy, active learning strategies, value of science learning, performance goal, achievement goal, and environmental stimulation. These factors collectively explained 56.49% of the total variance. The Science Attitude Scale was used to assess criterion-related validity, and the correlation coefficient between the two scales was found to be .73. For internal consistency reliability, Cronbach's alpha coefficients were calculated for each factor and the overall scale. The reliability coefficients for the individual factors ranged from .54 to .85, while the reliability coefficient for the entire scale was .87. These results indicate that the scale is valid and reliable. The highest possible score on the scale is 165, while the lowest possible score is 33.

Observation Forms

During the implementation process, the researcher acted as a participant observer and conducted systematic observations while taking detailed field notes. Additionally, observations were supported by video recordings throughout the process. The implementation was recorded using a camera to capture the student, the student's movements, and all virtual reality equipment in use. These video recordings were used to examine students' physical behaviors, verbal expressions, and actions while using the virtual reality application, as well as the interaction between the student and the researcher, the implementation of the virtual reality-based science instruction process, and students' thoughts and reflections throughout the process. Students' behaviors toward the VR application were documented using a structured observation form.

Student and Teacher Interview Forms

In this study, semi-structured interviews were conducted with fourth-grade students identified as participants and their classroom teachers. The interview questions were prepared before the implementation, and expert feedback was obtained from two specialists regarding the semi-structured interview form. Based on the expert feedback, the final version of the interview questions was developed, and the interviews were conducted accordingly. All interviews were audio recorded, and direct quotations from participants were included during the reporting phase. The student interviews aimed to explore how students experienced the virtual reality-based science instruction process, their opinions about the application, and their reflections on their development during the process. The teacher interviews focused on obtaining teachers' perspectives on the implementation process.

Researcher Diary and Student Diaries

Throughout the implementation process, the researcher maintained a researcher diary, while the students kept student diaries. After each instructional session, the researcher recorded reflections, emotions, observations, and impressions related to the lesson. Students were also asked to keep diaries to document their own experiences. In addition, the researcher

recorded personal reflections before and after interviews and thesis monitoring committee meetings through the researcher diary. This diary included detailed notes from the design phase of the study to the development of the virtual reality application and its implementation with participant students. As such, the diary served as a comprehensive record of the instructional process and captured the researcher's thoughts and emotions. The researcher diary thus became a valuable data source for describing the process in depth. Similarly, the student diaries reflected the students' feelings and thoughts about the lessons, depicting the process from the learners' perspective.

Role of the Researcher

Throughout this study, which was designed and implemented using a case study design, the first researcher acted as both a participant and an integral part of the process. During the implementation, the first researcher served as the program facilitator and participant observer during the observation phase. However, once the student wore the virtual reality headset, all instructional and assessment processes occurred entirely within the VR environment. Therefore, the first researcher did not take an active role during the virtual reality-based science instruction and instead assumed a guiding role. The second researcher supervised all stages of the study.

Data Collection Process

The data collection process was carried out in three stages: pre-tests (achievement and motivation scales), in-process observations and interviews, and post-tests. All data were collected through one-on-one sessions with each student. Quantitative measurement tools were administered both before and after the implementation. Once the student wore the virtual reality headset, all assessment procedures were conducted entirely within the VR environment. Observation data were gathered during the VR implementation, while interview data were collected following the VR experience. Both teacher and student interviews were conducted in the school library, where the application was implemented. Interviews with classroom teachers lasted between 10 and 15 minutes, whereas interviews with student participants ranged from 20 to 25 minutes. Each classroom teacher was interviewed twice-once before and after implementation. Five interviews were conducted for each student: some during the Science Coaster process and others following the application.

Data Analysis

A paired samples t-test was conducted to analyze the data obtained from the achievement test and the motivation scale. The effect size was calculated using the eta-squared (η^2) value. An eta-squared value between .01 and .06 indicates a small effect; values of .06 and above indicate a moderate effect; and values of .14 and above indicate a large effect (Cohen, 1988, as cited in Akbulut, 2010, p. 114). Qualitative data were analyzed using content analysis. Student and teacher opinions were categorized under thematic codes and supported by observation data.

Findings

This section presents the findings obtained in line with the overall aim and sub-questions of the study. The findings are structured to correspond to each sub-question, and the analysis headings were organized accordingly. An overview of these headings is presented in Figure 5.

Figure 5.
Findings related to the virtual reality-based science teaching process

Science Class with Science Coaster

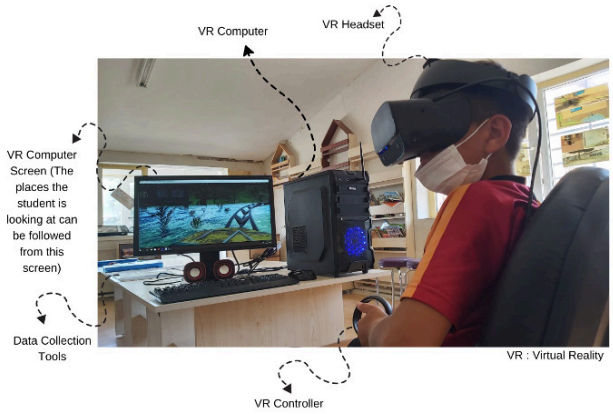
This section presents the findings related to the research question: "How is the virtual reality-based instructional process conducted in the fourth-grade primary school science course?" Based on the analysis of observation notes, the researcher diary, and video recordings, the instructional process was carried out in three main phases: lesson preparation, lesson implementation, and assessment and evaluation.

Lesson Preparation Process

Before the implementation, the virtual reality headset, controllers, computer, and software were prepared for each student. The student was introduced to the equipment and informed about the application. It was emphasized that the student could end the application at any time, and any technical or emotional issues were addressed accordingly. Before starting the session, efforts were made to ensure the student was physically and psychologically ready for

the experience. An illustrative example of this process is presented in Figure 6.

Figure 6.
Lesson preparation phase



Lesson Implementation Process

The implementation was carried out using the two-part learning experience offered by the Science Coaster virtual reality software: the underground and space journeys. During this process, the researcher intervened only during data collection intervals. In both parts of the experience, students were asked to share their impressions of the application, including their opinions on its instructive features, engaging aspects, and challenging parts. At various stages of the application, narrated explanations, visuals, and interactive content were used to activate students' prior knowledge and support the construction of new knowledge. The underground section addressed concepts such as layers, rocks, minerals, and fossils, while the space section focused on Earth's movements and the solar system. Each part included interactive activities designed to support student learning.

The student named Umut reflected his thoughts on the lesson process in his diary as follows (Student Diary – Umut):

> *"...When I entered the classroom, Teacher Fatih was there. There were many different things in front of him... He explained what each item was. There was a computer, a headset, and a controller. There was also a really cool video on the computer. Then he put the headset on me and showed me the video. Then he took it off and explained what I was going to do. Then I put the headset back on. I got on the train. I saw the Earth, houses, and cars. Then I entered a mine. I learned about minerals there. The teacher asked me questions. I answered them. Then I went to space. I saw the sun and the planets. It was great."*

Assessment and Evaluation Process

At the end of each section, feedback on students' learning was collected through assessment activities developed within the virtual reality environment. In the underground section, students demonstrated their knowledge of the topics by using the virtual controller to select the correct boxes displayed on glass domes. In the space section, concepts related to the subject matter were presented visually within the roller coaster environment, and students were asked to indicate the correct locations.

These assessment activities were supported by the screen inside the roller coaster vehicle, auditory instructions, and accompanying visuals.

Journey to Achievement with Science Coaster

In line with the study's second sub-question, "How does the academic achievement of fourth-grade primary school students change in a virtual reality-based science course?", the effect of the virtual reality-based science instruction process on students' academic achievement was examined. For this purpose, the Achievement Test for the Science Unit: The Earth's Crust and the Movements of Our Planet was administered before and after the implementation. The data obtained were analyzed using the SPSS software package. A paired samples t-test was conducted to determine whether the difference between pre-test and post-test scores was statistically significant. The results are presented in Table 1.

Table 1.
Paired samples t-test results for pre-test and post-test scores on the achievement test

Group	*n*	*M*	*SD*	*df*	*t*	*p*	η^2
Pre-test	33	14.75	6.04	32	-9,801	.000*	.75
Post-test	33	21.03	5.30				

*p<.05

The mean pre-test score of students on the achievement test was 14.75 (*SD* = 6.04), while the mean post-test score was 21.03 (*SD* = 5.30). According to the paired samples t-test results, there was a statistically significant difference between the pre-test and post-test scores ($t(32) = -9.801$, $p = .000$). Furthermore, the calculated η^2 value was greater than .14, indicating a large effect size. This result demonstrates that the implementation significantly improved students' academic achievement.

Qualitative data also supported quantitative findings. The researcher diary and interviews with students and teachers revealed the positive impact of the process on learning outcomes. Students' explanations of the concepts covered during the application indicated a high level of content comprehension. For example, one student, Hatice, explained the formation of day and night by stating: "The Earth rotates. If it sees the sun, it is daytime; if not, it is night." One of the classroom teachers, Secil, noted that students were inclined to express what they had learned spontaneously and emphasized that even students who struggled academically could grasp the content: "They have

learned quite a lot. I saw that even students who are not academically strong could explain how day and night occur."

These findings indicate that the virtual reality-based instructional process enhanced students' cognitive gains in the science course and supported learning content retention.

Journey to Motivation with Science Coaster

Within the scope of the study's third sub-question, "How does the motivation level of fourth-grade primary school students change in a virtual reality-based science course?", the study investigated whether students' motivation levels changed during the virtual reality-based science instruction process. For this purpose, the Motivation Scale for Science Learning was administered before and after the implementation, and the data were analyzed using the SPSS software package. The scale consists of six factors: self-efficacy, active learning strategies, value of science learning, performance goal, achievement goal, and environmental stimulation. Pre-test and post-test scores for all factors were compared, and according to the results presented in Table 2, statistically significant increases were observed across all factors.

In the self-efficacy factor, the students' mean pre-test score was 16.30 (*SD* = 2.99), while the mean post-test score was 24.24 (*SD* = 5.16). The result showed that this difference was statistically significant ($t(32) = -7.751$, $p = .000$). The calculated effect size was $\eta^2 > .14$, indicating a large effect. Qualitative data also support this finding. For example, in his student diary, Enes stated: "Science isn't that difficult. When schools open and I go back to class, I think I will get good grades in science...", expressing a positive shift in his self-efficacy beliefs regarding the subject. Observational notes by the researcher also support this finding: "Even when students struggled during data collection or application phases in the Science Coaster activity, they did not give up and persistently tried to find the correct answers." In the active learning strategies factor, the mean pre-test score was 23.09 (*SD* = 4.78), and the post-test mean was 26.97 (*SD* = 3.83). This difference was statistically significant ($t(32) = -7.141$, $p = .000$) and had a large effect size ($\eta^2 > .14$). Qualitative data indicated that students continued to make efforts to learn even when they encountered difficulties during the application. For instance, a student named Alparslan reflected on the experience: "I did not understand the topic at first. It was hard. I wanted to see it again, to hear and see it one more time... When I listened again, I understood." This statement shows that the student took control of his learning process and exhibited strategic learning behavior.

In the value of science learning factor, the students' mean pre-test score was 18.28 (*SD* = 4.20), while the mean post-test score was 20.93 (*SD* = 2.90). The difference was found to be statistically significant ($t(32) = -5.245$, $p = .000$), with a large effect size ($\eta^2 > .14$). A student named Nisa articulated the connection between the content learned and daily life as follows: "Actually, the topics we learn in science exist in real life too. I realized in this lesson that if I learn them here, I can also use them in real life." In the performance goal factor, the mean pre-test score was 7.18 (*SD* = 2.50), and the mean post-test score was 10.27 (*SD* = 1.91). This statistically significant difference ($t(32) = -5.245$, $p = .000$) also demonstrated a large effect size ($\eta^2 > .14$). The researcher reflected on this in the diary as follows: "All of the students were very eager to participate and experience the application... They did everything simply because they wanted to and enjoyed it." This statement highlights those students engaged in the process with intrinsic motivation, without needing external rewards or supervision.

In the achievement goal factor, the mean pre-test score was 16.09 (*SD* = 3.90), while the post-test mean

Table 2.

Paired samples t-test results for pre-test and post-test scores on the Motivation Scale for Science Learning

Factor	Group	*n*	*M̆*	*SD*	*df*	*t*	*p*	η^2
Self-efficacy	Pre-test	33	16.30	2.99	32	-7.751	.000*	.65
	Post-test	33	24.24	5.16				
Active Learning Strategies	Pre-test	33	23.09	4.78	32	-7.141	.000*	.61
	Post-test	33	26.97	3.83				
Value Of Science Learning	Pre-test	33	18.28	4.20	32	-5.148	.000*	.45
	Post-test	33	20.93	2.90				
Performance Goal	Pre-test	33	7.18	2.50	32	-5.245	.000*	.46
	Post-test	33	10.27	1.91				
Achievement Goal	Pre-test	33	16.09	3.90	32	-8.582	.000*	.70
	Post-test	33	20.33	2.54				
Environmental Stimulation	Pre-test	33	14.33	3.53	32	-16.308	.000*	.89
	Post-test	33	25.90	1.96				
Overall Motivation	Pre-test	33	95.27	13.40	32	-14.481	.000*	.87
	Post-test	33	128.66	12.50				

*p<.05

was 20.33 (*SD* = 2.54). This difference was statistically significant (*t*(32) = -8.582, *p* = .000), and the η^2 value of .70 indicates a large effect size. A student named Ömer expressed his motivation to re-engage with the application, stating: "I learned so many new things. I had never seen them before. Moreover, I did it, like, I got it right, and I was happy. That is why I want to do it again." One of the most remarkable increases was observed in the environmental stimulation factor. The mean pre-test score in this category was 14.33 (*SD* = 3.53), while the post-test score was 25.90 (*SD* = 1.96). This difference was highly statistically significant (*t*(32) = -16.308, *p* = .000) and indicated a very large effect size (η^2 = .89). These results suggest that students found the virtual reality environment highly engaging and encouraging for learning. A student named Bilal described the experience: "It was exciting... It was very different. Different from other lessons... It was not just a lesson -I saw it and lived it." The researcher also noted in the diary: "Most students showed interest in the science content, commented, and wanted to touch the materials. Even after the session ended, they were reluctant to take off the VR headset and wanted to keep exploring the content."

Regarding overall motivation scores, the students' mean pre-test score was 95.27 (*SD* = 13.40), while the mean post-test score was 128.66 (*SD* = 12.50). This difference was statistically significant (*t*(32) = -14.481, p = .001) and demonstrated a large effect size (η^2 > .14). Observations made by the classroom teachers also confirmed the increase in students' motivation levels. Teacher Leyla noted a marked increase in students' interest in the subject and their enthusiasm for further science instruction: "They asked me, 'Teacher, when are we going to do another science lesson? Can we also study the seasons?' So they were motivated." Likewise, students directly expressed the impact the experience had on them. For example, a student named Turan stated: "Now I like science lessons even more...", indicating a positive change in his attitude toward learning.

These findings show that virtual reality-based science instruction led to significant improvements across multiple dimensions of student motivation. In particular, the learning environment's structure, the interaction level, and the way content was presented increased students' self-efficacy, effort, perceived value of the subject, and willingness to engage with the lesson.

Science Coaster Through the Perspectives of the Participants

This section presents the findings related to the study's fourth sub-question: "What are the views of fourth-grade primary school students and their classroom teachers regarding the virtual reality-based science course?" Qualitative data were collected through student diaries, interview forms, observation notes, and teacher interviews. The following themes were identified based on the content analysis of these data sources.

The Realistic and Immersive Nature of the Application

Students perceived the virtual reality environment as highly realistic and engaging. Burak remarked, "I think lessons are better with virtual reality because it feels like you are actually there." Similarly, Esra stated, "It does not feel real when watching videos, but here it was very realistic." Ayşe, reflecting on the space section, said, "The feeling of being in space was extraordinary. It felt like I was actually there." Observation notes also indicated that students physically responded to the experience. For instance, Enes lifted his feet when encountering a sea scene; Sena ducked, thinking she might hit a sign in the mine; and Betül expressed the immersive nature of the experience by saying, "I want to get off the vehicle, but I cannot. It feels like I am going to fall." Classroom teacher Ms. Seçil shared her observations as follows: "Even I felt like I was there. It was as if the whole system was beneath my feet. It felt real." Participants' perception of the application as realistic and immersive supports the potential of virtual reality to create student-centered, experience-based learning environments in science education.

The Enjoyable Nature of the Application

One of the most frequently expressed views was that the application was enjoyable. Masal stated, "It was so much fun. I wish we could do it again." Zeynep remarked, "You are having fun and seeing everything come alive simultaneously." Ahmet described his experience: "I was inside the vehicle... sometimes it sped up, sometimes it slowed down. It felt like I would fall- it was so much fun." The researcher also reflected on this in the diary: "Above all else, the students truly enjoy the application... the fact that it is not only instructive but also entertaining makes them even more eager to participate." The fact that students found the application enjoyable contributed to developing positive attitudes toward the science course and increased their willingness to engage voluntarily in the learning process.

The Instructive Nature of the Application

A large portion of the participants emphasized the instructive aspect of the application. Nisa stated, "In regular lessons, you do not really understand what is going on, but here you can see it up close and understand it better." Ömer commented, "Actually, if all lessons were like this, they would be more instructive." Alparslan expressed the educational potential of the application by saying, "I can learn new things with this application. Everything is alive." Classroom teacher Ms. Leyla described the instructive

quality of the application as follows: "It takes on the role of a teacher... It teaches abstract topics by concretizing them in the students' minds." Similarly, the researcher noted in the diary: "The students were very excited, but they also learned. Even though the topic was unfamiliar, they could answer nearly all the questions." Participants' perception of the application as instructive highlights the effectiveness of virtual reality in concretizing abstract and conceptual topics, particularly in science education.

The Opportunity to Experience Events/Phenomena for the First Time

Students stated that they experienced many concepts and phenomena for the first time during the application. Turan remarked, "It was the first time in my life I saw a volcano... but this time I saw it for real." Emine said, "I went to space and saw the sun and Mars for the first time." Ali emphasized his experiential gain by stating, "I always heard about the layers, but I had never seen them. Now I know what they look like." Field notes also supported this observation. According to the notes, Ali exclaimed, "Wow, we are in space! This is my first time in space," while Ömer said, "There are planets here... I am seeing them now." The researcher summarized this phenomenon in the diary: "Although they had previously seen these things in books, videos, or pictures, the fact that they said it was the first time they were seeing them seems to be related to the way they experienced the application as a real event." The participants' expressions of encountering many concepts for the first time through the application illustrate that virtual reality allows students to engage with content that is otherwise difficult to access.

The Motivating Nature of the Application

Students demonstrated high eagerness and excitement to participate in the application. Emine stated, "I was very excited to come here... Science lessons are actually fun." Yunus expressed, "It was something different. That is why I really enjoyed participating in the lesson." Deniz emphasized his effort to understand a complex topic by saying, "I told myself I could do it... Then, after thinking about it carefully, I understood the topics." The researcher reflected on this in the diary: "Tuncay said, 'If you explain all the topics with these glasses, I will learn everything.' This indicates that students' belief in their ability to understand the content has increased." In Bilal's student diary, he wrote, "Now I like science lessons. Science is important, so now I like it." This statement shows that the application transformed the student's attitude toward science learning. Students' enthusiastic participation and their efforts to learn highlight the intrinsic motivational effect of the virtual reality application. These findings reveal that both students and teachers positively evaluated science instruction conducted through virtual reality. The lesson was found to be effective, particularly due to features such as realism, instructiveness, enjoyment, and motivational quality.

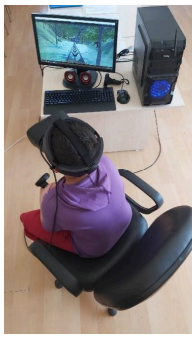
Challenges Encountered During the Journey

This section presents the findings related to the study's fifth sub-question: "What problems were encountered during the virtual reality-based science course conducted in the fourth grade of primary school?" The findings were examined under two main themes: technical and physical issues, and student- and experience-related problems.

Technical and Physical Issues

Due to the inherent nature of virtual reality technology, various technical and physical problems were encountered during the implementation process. The most frequently observed issues included software updates, internet connectivity, power outages, hardware malfunctions, and adjustments related to using the virtual reality headset. For example, the researcher noted in the diary: "At the beginning of the application, I noticed that the virtual reality headset was not displaying any visuals... The Oculus software requested an update, but due to insufficient internet at the school, I had to use mobile data... After the update, the Unity software also produced errors... All these processes took approximately one hour." According to the findings, power outages also directly affected the process: "Today, the electricity went out... Despite waiting three hours, the power did not return, so I had to send the students home. The program was seriously disrupted." One hardware-related issue involved the graphics card: "The graphics card malfunctioned... I turned off the devices and waited for a while, suspecting overheating... After adjustments, the system stabilized, but we still lost significant time." Although the virtual reality headset used during the application can track the student's gaze direction, it is impossible to observe externally whether the image inside the headset is clear (see Figure 7).

Figure 7.
Screenshot from the virtual reality application implementation phase - 1



As a result, whether the student had a clear view inside the headset could only be determined based

on the student's feedback. The headset's failure to properly fit the shape of the head emerged as a significant physical issue. In particular, for some students with smaller head sizes, the headset did not fit securely, negatively affecting the image quality: "No matter what I did, the student reported that the image was not clear... The student's head is quite small, and the headset does not fully fit even at the narrowest setting." Additionally, issues related to hair styling or wearing a headscarf prevented the proper placement of the headset. For some students who wore glasses, it was noted that using the headset and glasses was difficult, diminishing the image quality.

Student- and Experience-Related Issues

Findings indicate that some students exhibited anxiety at the beginning of the application. This apprehension was often rooted in prior negative virtual reality experiences. Students had developed prejudices due to fast and frightening content encountered in a VR truck previously available at the school. A student coded as Hatice expressed this in her diary: "I liked everything about the application, but I was afraid because it was fast. I thought it would be like the truck at school before. However, it was not like that; it was slow..." Conversely, students with prior positive VR experiences participated in the application with greater enthusiasm and excitement. This suggests that past experience is a significant variable influencing student attitudes. Another issue identified was negative parental attitudes toward the process. Despite informed consent forms being sent before the study, some families opposed the application, and misconceptions about the research arose. The researcher noted in the diary: "Among families, false information such as 'They are from X University and will conduct experiments on our children' spread... This negatively affected participation rates." Notably, a student named Sena was initially unable to participate but later convinced her family to allow her involvement, underscoring the fragility of the process.

The technical, physical, and pedagogical challenges encountered during the study highlight the necessity for planned and flexible integration of virtual reality technologies into educational settings. Applications carried out without consideration of factors such as technical infrastructure, hardware compatibility, student experience, and parental attitudes were found to disrupt the process. These findings offer important insights for future implementations of similar applications.

Overcoming Challenges Encountered During the Journey

This section presents the findings related to the study's sixth sub-question: "How can the problems encountered during the virtual reality-based science course conducted in the fourth grade of primary school be addressed?" The findings were examined under two main themes: solutions to technical and physical issues, and solutions to student- and experience-related problems.

Solutions to Technical and Physical Issues

Strategies to address the technical and physical problems encountered during the research process were shaped within the framework of hardware backups, system checks, and alternative planning. The researcher took various precautionary measures to prevent disruptions caused by software updates, hardware failures, or power outages. In this context, the use of backup devices proved to be an effective solution to systemic issues experienced during the operation of the virtual reality application. The researcher noted in the diary: "Due to a problem with the graphics card, no image was displayed. I activated the backup computer and continued the application." This experience highlights the importance of having backups for high-performance hardware components, especially in virtual reality systems. However, not all technical problems could be resolved. For instance, due to the inflexibility of the headset, students with smaller head sizes experienced improper fitting of the headset, resulting in unclear images. This problem remained unresolved throughout the application. Similarly, students who wore glasses faced technical limitations, as the headset could not accommodate their glasses, leading to difficulties in achieving clear visuals; no solution was found for this issue during the implementation. Preventive measures, alternative plans, and hardware backups facilitate the smooth execution of the process in resolving technical problems. Nonetheless, structural limitations such as the ergonomic design of virtual reality equipment may hinder the equal functionality of the process for all participants.

Solutions to Student- and Experience-Related Issues

Most of the anxieties experienced by students during the implementation process stemmed from prior negative experiences. In particular, a previous VR truck experience at the school involving fast and frightening content led some students to develop prejudices against the current application. To address this, detailed information about the content was provided before the application, and students were assured that they could stop the process at any time. The researcher noted the following in the diary: "Before starting, Ahmet asked whether the application would be too fast and if it contained frightening elements. I explained the content in detail, and afterwards, I observed that he felt more at ease." This approach efficiently ensured the children's emotional security and increased participation. Similarly, some parents misunderstood the application upon seeing the university's name, which disrupted the process. Classroom teachers and school administration

intervened to resolve this issue and provided reassuring information. This highlights the influential role of trusted social actors in students' participation decisions. The researcher's diary reflected this: "Sena could not obtain permission from her family for a long time. She observed the application from outside during the process but ultimately convinced her family and participated." As the findings indicate, comprehensive pre-application information for students and parents, strengthening trust relationships, and active use of teacher support are critical to the success of the process in reducing prejudices.

Discussion and Conclusion

The primary aim of this study was to explore how the virtual reality-based science instruction process developed for fourth-grade primary school students is conducted. The first finding revealed that the process can be implemented in three main phases: lesson preparation, lesson delivery, and assessment and evaluation. During the lesson preparation phase, introducing students to virtual reality technology and providing instructions related to the application process were found to be important for ensuring students' readiness to use the technology. In the lesson phase, students' interactive engagement using the virtual reality controller and ongoing communication with the teacher supported active learning and maintained the pedagogical integrity of the process. The assessment and evaluation phase conducted at the end of the lesson contributed systematically to the instructional process by identifying students' learning gains and detecting learning gaps.

The quantitative and qualitative data collected throughout the study demonstrated a significant increase in students' academic achievement in the science course. The achievement tests administered at the beginning and end of the application, along with observation forms, researcher and student diaries, and interviews with students and teachers, supported this result. The visual and auditory presentations facilitated by virtual reality technology, its interactive content, and the high level of immersion provided contributed to deepening students' learning processes. These findings are consistent with existing literature demonstrating the positive effects of virtual reality applications on academic achievement (Akkaya, 2016; Çakır, 2019; Evci, 2022; Karataş, 2020; Özer, 2017; Sakız et al., 2014; Uysal, 2020).

Similar findings regarding the positive impact of virtual reality technology on academic achievement have been reported in numerous studies (Akman & Çakır, 2020; Bouta & Retalis, 2013; Değirmenci Kurt, 2022; Kim & Kei, 2017; Villena Taranilla et al., 2019; Yang et al., 2010; Yang et al., 2021). Aktamış and Arıcı (2013) determined that virtual reality-supported science instruction increases academic achievement, while Sarıoğlu (2019) emphasized that science instruction conducted with virtual reality is particularly effective in concretizing abstract concepts. A meta-analysis conducted by Villena Taranilla et al. (2019) also concluded that virtual reality applications enhance students' academic achievement. Liu et al. (2022) reported that virtual reality-based science instruction developed at the primary school level significantly increased students' academic success. Similarly, studies by Fokides and Chachlaki (2020), Liou et al. (2017), and Sun et al. (2010) demonstrate the positive effects of virtual reality applications in science education.

Another key finding of the study is that students' motivation toward science learning improved across factors such as self-efficacy, active learning strategies, the value of science learning, performance and achievement goals, and environmental stimulation. This result is supported by quantitative data obtained from the motivation scale and observation forms, researcher and student diaries, and interviews. The materials used in virtual reality environments, which offer highly realistic world simulations, fostered a strong desire to learn among students, thereby enhancing their motivation (Laver et al., 2015). Similarly, studies by Garduño et al. (2021), Fokides and Chachlaki (2020), Liou et al. (2017), and Liu et al. (2022) have demonstrated that virtual reality increases motivation in learning environments. Değirmenci Kurt (2022) reported that virtual reality-supported mathematics instruction elevated students' motivation, a finding supported by both test data and parental interviews. Beyoğlu et al. (2020) found that mixed reality applications increase motivation, while Yang et al. (2021) highlighted contributions to writing motivation. Motivational benefits of virtual reality have also been identified in history and language learning contexts (Villena Taranilla et al., 2019; Yang et al., 2010). Additionally, Boda and Brown (2020) and Sun et al. (2010) showed positive effects of virtual reality on attitudes and motivation toward science lessons. However, some studies (Pateraa et al., 2008; Uysal, 2022) have indicated that virtual reality does not always produce significant motivational effects. This suggests that contextual factors, such as the type of software used, duration of application, and student age, may play a determining role in its motivational impact.

Another significant finding of the study is that participants perceived the virtual reality application as realistic, immersive, enjoyable, instructive, and motivating. The vast majority of participants reported that the content presented in the virtual reality environment was impressive and conducive to learning. Additionally, students expressed that through this application, they could observe phenomena and events for the first time that they had not previously

experienced. The sense of "presence," a fundamental characteristic of virtual reality, plays a decisive role in enhancing the instructional effectiveness of such applications. Beyoğlu et al. (2020) demonstrated that mixed reality applications generate high levels of excitement and motivation among students, while Dilmen (2020) found that augmented reality makes lessons more enjoyable. Yang et al. (2021) reported that virtual reality-based instructional methods are more satisfying than traditional methods; Sulisworo et al. (2022) noted that students found virtual reality applications highly immersive. Similar to this study, Liu et al. (2022) emphasized that virtual reality-based instruction positively affects students' academic achievement, science motivation, and attitudes toward learning, while reducing cognitive load. Students reported positive experiences with the application and indicated a high level of interest in lessons conducted using virtual reality.

Another key finding of the study is that technical and physical issues and student- and experience-related problems were encountered during the implementation process. Technical and physical problems primarily stemmed from hardware and infrastructure elements such as computers, virtual reality headsets, software, internet connectivity, and electricity. Student- and experience-related issues were associated with students' apprehensions due to prior experiences and parental prejudices toward virtual reality technology. These findings are consistent with studies conducted by Sulisworo et al. (2022) and Lim et al. (2006). Lim et al. (2006) emphasized that factors such as time constraints, school infrastructure, and parental involvement pose significant barriers to integrating virtual reality technology into educational programs. Solutions to the technical and physical problems encountered in the study were implemented using backup devices and software. Using wireless and standalone virtual reality headsets with their own operating systems is recommended, as these battery-powered devices also offer advantages against issues such as power outages. Additionally, flexible fabric-based and adjustable headsets are preferred over rigid plastic headsets that do not fit securely, and compatible lens adapters should be used for students who wear glasses. Such strategies are considered important to prevent problems that may arise in similar studies.

This study comprehensively examined the effects of virtual reality-based science instruction on fourth-grade primary school students. The results indicate that the instructional process can be effectively conducted within a three-phase structure consisting of preparation, implementation, and evaluation. Also, the results revealed a significant increase in students' academic achievement in the science course. Additionally, students' motivation toward science learning showed improvement across dimensions such as self-efficacy, active learning strategies, the value of science learning, achievement goal, performance goal, and environmental stimulation. Qualitative findings supported this development, demonstrating that students perceived the application as realistic, instructive, enjoyable, and motivating. Various challenges were observed throughout the process, including technical issues related to the VR headset, hardware incompatibilities, and students' apprehensions from prior experiences. However, practical solutions were implemented through the use of backup equipment, flexible planning, and collaboration between families and teachers.

This study suggests that virtual reality technology is not merely a technical innovation but also a pedagogically valuable instructional tool. It possesses strong potential in primary science education, particularly concerning concretization, experiential learning, and motivation enhancement. The planned, structured, and student-centered integration of virtual reality in educational settings may provide significant contributions toward making learning processes more meaningful and enduring.

Limitations and Suggestions for Future Research

This study was conducted with fourth-grade students from a single school and did not include a control group. This limitation restricts the ability to draw causal inferences. Future studies should employ larger samples, incorporate different types of schools and socioeconomic levels, and adopt experimental designs that include control groups. The virtual reality application named Science Coaster used in this study was developed solely for the Earth's Crust and the Movements of Our Planet unit. Developing virtual reality software for other science units and other subject areas and conducting studies to evaluate their effectiveness would make important contributions to the literature. Moreover, this study was limited to the fourth-grade level. Implementing similar applications across different age groups would be meaningful in revealing the age-related effects of virtual reality applications. The study utilized structured data collection instruments such as achievement tests and motivation scales. Future research could enrich the scope by incorporating alternative data collection tools, particularly game-based assessment systems, process-oriented evaluation instruments, and biometric data collection techniques (e.g., eye tracking, galvanic skin response). Technical and physical issues and some limitations related to student experience were encountered during the research process. While some problems were resolved with the researcher's technical knowledge and hardware support, others remained unaddressed. Accordingly, future studies are expected to achieve more effective results by

developing applications through interdisciplinary teams consisting of professional software developers, graphic designers, sound engineers, programmers, and educational technology experts.

For future virtual reality-based applications, it is recommended to develop multi-user support, task-based content that enables user interaction, AI-supported learning systems, personalized learning pathways, feedback systems to monitor students' progress, and designs compatible with low-cost hardware. Additionally, social learning processes in virtual reality environments can be supported through systems that encourage collaboration among students by enabling synchronous multi-user modes. Finally, offering elective courses focused on virtual reality in teacher education faculties can enhance prospective teachers' knowledge and skills regarding virtual reality technologies, thereby strengthening their competencies to integrate these technologies into instructional practices. Field applications conducted in collaboration with schools through virtual reality laboratories established within universities will further support this process.

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Enhancing Systems Thinking in Elementary Science Education: A STEM-Based Approach for Fourth-Grade Learners

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Abstract

The present study investigates the impact of STEM-based activities on the systems thinking skills of fourth-grade students. The research aims to determine whether STEM-integrated learning enhances students' ability to analyze, synthesize, recognize relationships, and develop a holistic understanding of scientific concepts. The study employed a quasi-experimental design with a sample of 66 fourth-grade students from the Muscat Governorate, Oman, divided into two groups: a control group that received traditional instruction and an experimental group that engaged in STEM-based activities. A pre-test and post-test measuring system for thinking skills was administered to both groups. Data were analyzed using an independent samples t-test to assess differences in post-test scores between the groups. The findings revealed statistically significant differences ($p < 0.05$) in favor of the experimental group in specific systems thinking skills, including analysis, synthesis, recognizing relationships, and overall perception. These results suggest that STEM-based activities effectively enhance students' cognitive abilities, allowing them to engage in complex scientific reasoning. The study underscores the importance of STEM-based learning in elementary science education and recommends integrating STEM activities to promote higher-order thinking skills. Further research is encouraged to explore the long-term impact of STEM interventions, particularly among older students, to assess their broader influence on cognitive and academic growth.

Keywords:

STEM-based Learning, Systems Thinking Skills, Elementary Science Education, Cognitive Development, Experimental Study

Introduction

The 21st century has ushered in rapid and transformative changes across all aspects of life. Among the most dynamic of these is education, which has evolved to meet the demands of the 'Knowledge Economy Age' (Shahat & Al-Balushi, 2023). As educational outcomes play a pivotal role in societal advancement, there is a growing need to adopt teaching strategies that effectively prepare learners (Ohle-Peters & Shahat, 2025). Educators continue

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to seek instructional methods that align with modern pedagogical standards and promote active student engagement (Karalar et al., 2021). In science education, which emphasizes inquiry and hands-on learning, innovative strategies are essential for cultivating skills such as critical thinking, problem-solving, and analytical reasoning (Ambusaidi et al., 2022; Shahat et al., 2022). However, traditional instruction often prioritizes theoretical knowledge over practical application, limiting students' readiness for real-world problem-solving (Al-Qudayb, 2011).

To address this gap, interdisciplinary approaches like STEM (Science, Technology, Engineering, and Mathematics) have gained prominence. STEM promotes integrative, hands-on learning experiences that help students connect academic content to real-life contexts and develop key skills such as scientific reasoning, logical analysis, and decision-making (Al-Mazrouei & Olayan, 2020; Sanders, 2009; Shahat et al., 2024a). STEM-based activities are designed to merge content from multiple disciplines, enabling students to make meaningful connections and engage in deeper learning (Shahat et al., 2022, 2025). Such integration supports not only content mastery but also the development of cognitive skills that can be applied across subject areas. For example, 'systems thinking' has emerged as a valuable cognitive approach in STEM contexts. Unlike linear thinking, which follows sequential cause-and-effect reasoning, systems thinking encourages a holistic understanding of complex issues. It enables students to identify relationships, recognize patterns, and integrate analytical and synthetic reasoning to develop comprehensive models and solutions (Mohamed, 2009; Shahat et al., 2024c). It is a cognitive process that allows learners to represent and address problems based on their understanding of interconnected elements (Acar et al., 2018; York et al., 2019; Shahat et al., 2023). This study adopts the definition of systems thinking as a multifaceted cognitive skill that combines analysis, synthesis, and model-based reasoning (Al-Balushi et al., 2022).

Recognizing the growing emphasis on STEM education, this study explores its potential to enhance systems thinking skills among fourth-grade students. It contributes to the field by addressing a critical gap in the literature on how STEM-based activities influence cognitive development, particularly in younger learners (Shahat & Al-Amri, 2023). It also aligns with the goals of the Fourth Industrial Revolution, emphasizing the need to equip learners with skills necessary for navigating an increasingly interconnected world (Al-Balushi et al., 2022). Furthermore, this research supports the incorporation of STEM-based strategies into science curricula in the Sultanate of Oman, reinforcing their role in enhancing student engagement and real-world application of scientific concepts (Shahat et al., 2024c).

Problem Statement

Al-Ghamdi (2019) highlighted the need for educational approaches that enhance students' creative and innovative thinking skills. It is argued that educators need to encourage diverse forms of thought, such as critical thinking, that can benefit them in everyday contexts. These methods allow students to process and analyze the information they receive, helping them discover underlying relationships. Studies on systems thinking have demonstrated its positive impact on student achievement; some research has focused on what it is and how it is developed, while others have explored strategies for instilling these skills in students (Al-Jubaili, 2017; Al-Qudayb, 2011; Shahat et al., 2024a, 2025; York et al., 2019).

In order to meet Oman's Vision 2040 goals, the Ministry of Education is committed to enhancing and modernizing educational methods to obtain maximal outcomes. The vision 2040 goals expressly state that education must equip individuals to enter the workforce ready to compete and contribute to a knowledge-based economy. Educational program and curriculum development combined with diverse and innovative teaching methods are required to realize this vision (Oman Vision Document, 2019–2040; Shahat & Al-Balushi, 2023). Therefore, this study will investigate the use of STEM activities in science instruction to determine the impact of this contemporary approach on students' systems thinking.

A pilot survey was conducted by the researchers on a sample of Omani science teachers teaching grades 1-4. Findings revealed insights regarding students' proficiency in advanced thinking skills, including systems thinking. Almost 80% of the teachers surveyed believed students have limited ability to analyze and link relationships within scientific problems, although they perform well on straightforward questions. Additionally, 89% of the surveyed teachers indicated that students find it challenging to answer questions requiring higher-order thinking skills, such as analysis, synthesis, and a deep understanding of relationships. These findings align with previous studies, which have indicated the necessity of incorporating STEM-based activities to foster systems thinking and enhance students' cognitive and problem-solving abilities (Shahat et al., 2024d). Given Omani students' lack of thinking skills, the researcher's educational experience and familiarity with the field, and the absence—based on the researcher's knowledge—of any previous studies in Oman examining the impact of STEM activities on systems thinking among fourth-grade students, this study was initiated.

Aim and Research Question

The study aims to investigate the impact of STEM-based educational activities on developing systems

thinking skills among fourth-grade science students. The research problem is summarized in the following main question: What is the impact of employing STEM-based activities in developing systems thinking skills among fourth-grade students?

To address this question, the study explores these specific sub-hypotheses:

H1.1: At the (α = 0.05) level, statistically significant differences in post-test scores for systems thinking skills will favor the experimental group over the control group.

H1.2: At the (α = 0.05) level, statistically significant differences between pre-test and post-test scores for the experimental group will favor the post-test, reflecting the impact of STEM-based activities.

Theoretical Framework and Literature Review

This section discusses the study's theoretical framework and reviews previous studies related to the current research topic, structured into two main areas: STEM education and systems thinking.

The STEM Approach

STEM is an interdisciplinary educational approach that integrates science, technology, engineering, and mathematics to foster engagement, motivation, and real-world relevance in learning (Al-Enezi & Al-Jabr, 2017; Shahat et al., 2023). The acronym STEM, which replaced the original "SMET" in 2001, reflects a deliberate shift to emphasize integration and the foundational role of these disciplines in driving innovation (Sanders, 2009). This rebranding aligned with global efforts to prepare students for the demands of the modern workforce. The British Association's report The Scientific Century, exemplified this shift in thinking by linking scientific advancement to national prosperity and calling for a renewed emphasis on science and mathematics education (Finegold et al., 2011).

The benefits of STEM education are well-documented. It encourages students to engage in real-world challenges, enhancing their critical thinking and problem-solving capabilities through engineering design principles and interdisciplinary integration (Jolly, 2016; Shahat et al., 2024a). It also promotes higher-order thinking, active engagement, collaboration, and communication—skills necessary for success in a technology-driven world (Shahat & Al-Amri, 2023). Each STEM discipline contributes distinct strengths: science develops inquiry and experimentation skills; technology applies scientific knowledge to practical contexts; engineering fosters design and spatial reasoning; and mathematics builds logical reasoning and pattern recognition (Shahat et al., 2024b). Together, these elements help students form deeper conceptual understanding and apply their learning across domains.

Applying STEM in practice requires a move away from traditional passive learning. The activities implemented typically involve hands-on, real-world problem-solving tasks. Pottenger et al. (2000) emphasized that STEM learning should be exploratory, collaborative, and rooted in real-life applications to make abstract concepts more meaningful for students (Shahat et al., 2024c). For example, students may be asked to design and build a model bridge using craft materials while applying principles of force, balance, and measurement (Al-Ghamdi, 2019). Another task could involve constructing a basic irrigation system for a school garden using recycled bottles, where students integrate knowledge of plant biology, fluid mechanics, and environmental sustainability (Abuthnain, 2021). These types of integrated activities require students to collaborate, hypothesize, test, and refine their designs—mirroring the engineering design process and reinforcing connections between science concepts and practical applications (Shahat et al., 2024a).

A growing body of research supports the effectiveness of STEM-based instruction. Al-Enezi (2020) found that integrating STEM activities improved academic achievement and scientific problem-solving among intermediate students. Similarly, Abdo (2019) reported enhanced creative thinking and academic performance among blind primary school students through STEM interventions. Karalar et al. (2024) confirmed that STEM-based strategies significantly improved higher-order thinking skills in comparison to traditional methods (Shahat et al., 2024a–c). These studies affirm that STEM approaches benefit diverse learners by strengthening both cognitive and practical competencies.

Beyond academic performance, several studies establish a strong relationship between STEM education and systems thinking. Abdurrahman (2023) found a significant positive correlation between STEM education and systems thinking and academic proficiency among basic education students. York et al. (2019) similarly identified links between STEM education and systems thinking and analytical decision-making. In Oman, Al-Lawatiya, (2014) reported significant differences in systems thinking based on gender and academic qualifications among Ministry of Education employees (Shahat et al., 2024a; Shahat & Al-Balushi, 2023). These findings support the integration of STEM-based learning as a tool to foster complex cognitive skills, including systems thinking.

STEM has become central to educational reform efforts globally (Acar et al., 2018). In Oman, it is a strategic component of educational modernization

aligned with Vision 2040. Integrating STEM into science curricula is viewed as a means to enhance students' analytical, creative, and collaborative abilities, ensuring they are equipped for the demands of a rapidly evolving technological landscape (Shahat & Al-Balushi, 2023; Shahat et al., 2024d).

Systems Thinking

Systems thinking is a cognitive approach rooted in mathematics, engineering, and computer science (Klir & Ashby, 1991). It emphasizes the analysis of interrelated system components, encouraging learners to understand problems holistically rather than in isolation (Shahat et al., 2024c). This mode of thinking aligns with the complexities of real-world situations, where components continuously influence one another.

As a cognitive framework, systems thinking enables individuals to identify causal relationships, construct mental models, and interpret complex structures (Shahat et al., 2024b). Scholars have outlined various skills central to systems thinking, such as pattern recognition, system decomposition, cause-effect analysis, synthesis, and evaluation. Al-Kubaisi (2010) contributed a framework detailing these competencies. Al-Qudayb (2011) further organized them into four categories: understanding systemic relationships, system analysis, system synthesis, and system evaluation. These categories mirror the structured cognitive progression required for effective problem-solving. In practice, this sequence begins with recognizing systemic relationships—identifying how parts influence one another within a system. This is followed by system analysis, which involves breaking down complex systems into manageable components. System synthesis then requires integrating these components into coherent models, helping learners develop generalizations and practical applications. Finally, system evaluation involves assessing the integrity and functionality of the models, refining them based on feedback and outcomes (Shahat et al., 2023).

These processes enhance interdisciplinary learning and real-world problem-solving capabilities. The comparison of various frameworks in Table 1 shows a consistent emphasis across the literature on four core cognitive functions underpinning systems thinking: understanding systemic relationships, system analysis, synthesis, and evaluation.

By adopting Al-Qudayb's framework, the current study ensures a comprehensive approach to systems thinking skill development. This alignment strengthens the study's theoretical foundation and supports its focus on structured cognitive processes such as analysis, synthesis, and evaluation.

Al-Qudayb's (2011) framework was chosen because it offers a structured, cognitively grounded model that integrates these functions into a coherent developmental progression. Unlike other frameworks that may emphasize isolated skills or context-specific applications, Al-Qudayb's model supports a balanced and transferable approach to systems thinking. It emphasizes not only the decomposition and analysis of systems but also the reintegration and evaluation of ideas—key capabilities for tackling real-world complexity.

This choice directly supports the study's focus by aligning the research with a pedagogically sound and theoretically robust framework that reflects the mental processes targeted in systems thinking education. It enables the study to systematically explore learners' development across analytical, synthetic, and evaluative dimensions, ensuring that the intervention addresses both cognitive depth and interdisciplinary applicability.

Finally, previous empirical research—ranging from quasi-experimental to mixed-method designs—has informed the current study's methodology. These studies guided the formulation of activity types, implementation strategies, and tailored research instruments. They also contributed to the study's hypothesis development and data analysis framework, ensuring methodological coherence and academic rigor.

Table 1

Comparison of Systems Thinking Skills Across Frameworks

Skill Category	Al-Qudayb (2011)	Al-Kubaisi (2010)	Al-Hakim (2018)	Shahat et al. (2023)
Understanding Systemic Relationships	Recognizing relationships within a system	Pattern recognition	Identifying causal links and dependencies	Recognizing relationships
System Analysis	Identifying and breaking down system components	Decomposing and analyzing subsystems	Cause-effect analysis	Analysis
System Synthesis	Integrating concepts to construct models and derive generalizations	Constructing systems and generalizing patterns	Synthesizing knowledge into structured frameworks	Synthesis
System Evaluation	Verifying accuracy, assessing performance, and proposing improvements	Assessing system integrity	Evaluating and refining systemic models	Holistic perception

Methodology

Design

This study employed a quasi-experimental design. Quantitative data was collected through a systems thinking achievement test administered to 66 fourth-grade students at Ajyal Muscat Basic Education School in Al-Amarat, Muscat Governorate. The research was conducted during the second semester of the 2023/2024 academic year, spanning from March 25 to April 21. The participants, all enrolled in morning sessions, were divided into two groups: an experimental group that engaged in STEM-based activities and a control group that followed traditional teaching methods. This design was selected for its effectiveness in comparing the impact of STEM-based instruction versus traditional methods on the development of systems thinking skills (Creswell, 2019). The study focuses on assessing the effect of STEM-based activities on four specific systems thinking skills: analysis, synthesis, understanding relationships, and holistic perception.

The study was limited to Ajyal Muscat Basic Education School in Al-Amarat. It was selected due to its proximity to the researchers and the cooperation of both the science teacher and the school administration. The sample consisted of 66 fourth-grade students, evenly divided into 33 students in the experimental group and 33 in the control group. To ensure fairness and minimize bias, their teacher randomly assigned students to the experimental and control groups before the study's implementation. This random assignment aimed to eliminate potential confounding variables, ensuring a more accurate assessment of the impact of STEM-based activities on systems thinking development (Shahat et al., 2023).

Instruments

Teacher's guide for implementing STEM-based activities

To support the implementation of STEM-based activities for the experimental group, the researcher developed a comprehensive teacher guide designed to facilitate systems thinking within an interdisciplinary STEM framework. This guide includes an introduction outlining the significance of STEM integration, clearly defined learning objectives, a theoretical framework linking STEM disciplines with systems thinking, and a procedural framework providing detailed lesson plans for one unit and instructional strategies. The selected unit, "Electricity and Magnetism," from the fourth-grade science curriculum (second semester), was chosen due to its strong potential for fostering systems thinking through hands-on STEM activities (Shahat et al., 2023). The unit's content naturally lends itself to interdisciplinary exploration, allowing students to engage in experiments, engineering challenges, and mathematical modeling that deepen their understanding of complex scientific phenomena.

The researchers followed a structured, multi-phase process to ensure the guide's effectiveness, relevance, and alignment with STEM education principles. First, a comprehensive literature review was conducted, drawing on prior research on STEM-integrated education. Studies such as Karalar et al. (2024) and Al-Enezi (2020) provided insights into best practices for designing STEM-based activities that helped in creating the guide. This led to an emphasis on active learning, hands-on experimentation, and interdisciplinary problem-solving (Shahat & Al-Balushi, 2023).

Following the literature review, the unit "Electricity and Magnetism" was analyzed through the lens of STEM education to ensure the effective integration of science, technology, engineering, and mathematics. Each lesson was created to allow a) scientific inquiry through experimentation and observation, b) interaction with technological applications such as simulations and digital tools, c) active participation in engineering challenges where students design simple circuits, electromagnets, and energy transfer models, and d) the application of mathematical reasoning through calculations, measurements, and data interpretation. This approach ensured that students engaged in interdisciplinary problem-solving while developing critical thinking skills.

The first draft of the teacher guide included an introduction explaining the role of STEM in developing systems thinking, a theoretical framework, and connections to real-world applications reinforcing the relevance of STEM-based learning. The guide aligned with the Omani Ministry of Education curriculum and the Cambridge international curriculum to ensure coherence with national and international educational standards. It incorporated structured lesson plans that included learning objectives, instructional activities, assessment strategies, and time allocations for various activities to ensure a balanced mix of hands-on, collaborative, and inquiry-based learning. Additionally, group-based and interdisciplinary STEM activities were designed to foster teamwork, creativity, and problem-solving.

To validate the guide's practicality, clarity, and instructional effectiveness, it was reviewed by six science education experts, including STEM-specialized teachers, Ministry of Education supervisors, and university educators with expertise in science education. Their feedback was used to refine the guide and improve its usability, lesson clarity, activity feasibility, and instructional scaffolding. The final version ensures that teachers can effectively implement STEM-based learning and facilitate student

engagement with scientific inquiry, engineering design, and real-world problem-solving (Shahat et al., 2024a).

Systems thinking test

The systems thinking test was designed to evaluate students' proficiency in key cognitive skills associated with systems thinking. Drawing from Al-Qudayb (2011) and recent studies (Shahat et al., 2024b), the researcher identified four primary systems thinking skills:

1. Analysis: breaking down complex systems into simpler subsystems, enabling students to recognize interconnections and understand systemic structures.
2. Synthesis: combining and integrating subsystems to construct a cohesive, functional system that promotes holistic problem-solving.
3. Recognizing Relationships: understanding connections between system components and their interactions within larger frameworks.
4. Holistic Perspective: developing a comprehensive understanding of topics while maintaining attention to details in order to foster a systems-level view of knowledge.

These skills guided the development of activities and test questions, ensuring a direct assessment of STEM activities' impact on systems thinking among fourth-grade students (Shahat et al. 2024c).

The test consisted of 16 multiple-choice questions, evenly distributed across the four identified skills:

- Analysis: 4 questions
- Synthesis: 4 questions
- Recognizing Relationships: 4 questions
- Holistic Perspective: 4 questions

The test was designed to match the age level of the target students and was short enough to be completed within one 45-minute lesson. It consisted of a balanced allocation of questions to provide a comprehensive measure of students' systems thinking capabilities across all targeted skills (Shahat et al., 2024d).

Validity and reliability

The systems thinking test was initially developed to align with cognitive abilities appropriate for fourth-grade students. The first draft consisted of 20 questions, designed to comprehensively evaluate students' proficiency in analysis, synthesis, recognizing relationships, and holistic perspective. To ensure the content validity of the test, a panel of experts reviewed the instrument. This panel included four science teachers, two specialists with master's degrees in science curricula and teaching methods, and an educational supervisor.

Following their feedback, adjustments were made to improve the test's clarity, suitability, and appropriateness for fourth-grade students. Specifically:

- Certain questions were removed, and others rewarded to ensure comprehensibility and age appropriateness.
- The number of questions was reduced, making the test more manageable and accessible for young learners.
- The final version was refined to better align with the educational level and STEM-based instruction implemented in the study (Shahat et al., 2024a).

To establish the reliability of the test, it was administered to a pilot sample of 35 fourth-grade students, and Cronbach's alpha was calculated using SPSS. The reliability analysis produced an overall coefficient of 0.76, indicating a satisfactory level of internal consistency, as recommended by Gay & Mills (2022). In psychometric testing, a coefficient closer to 1 reflects stronger reliability. This value confirms that the test reliably measures systems thinking skills among fourth-grade students (Shahat et al., 2024b).

The Cronbach's alpha coefficients for each system's thinking skill were also analyzed to ensure consistency across individual components of the test (see Table 2).

Although the Holistic Perspective skill scored slightly lower (0.65) than other dimensions, this result is not unusual and can be attributed to the broader, more abstract nature of holistic thinking. As holistic perspective focuses on big-picture reasoning, interconnected relationships, and overarching system dynamics, it is inherently more complex and subjective to assess compared to more structured cognitive skills like analysis or synthesis. Despite this, the score remains

Table 2

Cronbach's alpha coefficients for each system's thinking skill

Systems Thinking Skill	Cronbach's Alpha Coefficient	Reliability Interpretation
Analysis	0.79	High Internal Consistency
Synthesis	0.74	Satisfactory Reliability
Recognizing Relationships	0.77	Satisfactory Reliability
Holistic Perspective	0.65	Acceptable Reliability
Overall	0.76	Satisfactory reliability

within an acceptable range for the study's purposes and aligns with commonly accepted standards for reliability in educational research (Field, 2009). Furthermore, similar findings have been observed in previous research where higher variability in holistic thinking measures was noted due to its reliance on integrative, less linear cognitive processes, reinforcing the validity of this result.

With validity and reliability confirmed, the test was finalized for implementation in the main study. The results validate the test as a consistent and reliable instrument for measuring systems thinking skills among fourth-grade students. These reliability coefficients underscore the instrument's potential to accurately and consistently evaluate the targeted skills across the experimental and control groups (Field, 2009).

Procedures and data analysis

Two fourth-grade classes were randomly assigned to form experimental and control groups. To ensure equivalence between the groups before the intervention, an independent samples t-test was conducted on pre-test scores, calculating both mean scores and standard deviations for each systems thinking skill (Creswell, 2019; Shahat et al., 2024a).

The t-test results confirmed no statistically significant differences between the control and experimental groups across all systems thinking skills, thus establishing group homogeneity prior to the intervention. The results were as follows in Table 3:

These results confirm the absence of statistically significant differences between the groups, verifying group homogeneity and ensuring a reliable basis for post-intervention comparisons (Shahat et al., 2024b).

During the instructional phase, students in the experimental group participated in STEM-based activities specifically designed to enhance systems thinking skills, while the control group received traditional instruction. Upon completion of the instructional period, a systems thinking test was administered as a post-test to both groups to assess the impact of STEM-based learning (Shahat & Al-Balushi, 2023).

To evaluate the effectiveness of the intervention, several key statistical analyses were conducted:

1. Descriptive statistics (means and standard deviations) were calculated to establish baseline scores and track changes in post-test performance (Field, 2009).

2. Independent samples t-test was conducted to confirm initial group equivalence and identify any statistically significant differences in post-test scores between the experimental and control groups.

3. Paired samples t-test was used to compare pre-test and post-test differences within each group, providing insights into the specific impact of STEM-based activities on systems thinking skills in the experimental group compared to the control.

These statistical procedures comprehensively assessed the impact of STEM-based instruction, confirming the method's reliability and its effectiveness in enhancing cognitive skills related to systems thinking (Shahat et al., 2024b).

Results

To address the research question, What is the impact of employing STEM-based activities on the development of systems thinking skills among fourth-grade students?, and to test Hypothesis H1.1—At the α = 0.05 level, statistically significant differences in post-test scores for systems thinking skills will favor the experimental group over the control group—an independent samples t-test was conducted. The post-test scores for systems thinking skills were analysed to examine differences between the experimental and control groups, as summarized in Table 4.

Table 3

t-test results for the control and experimental groups across all systems thinking skills prior to the intervention

Systems Thinking Skill	Control Group Mean (SD)	Experimental Group Mean (SD)	t-value	p-value
Analysis	0.43 (0.24)	0.39 (0.26)	0.73	0.350
Synthesis	0.40 (0.29)	0.36 (0.24)	0.69	0.284
Recognizing Relationships	0.25 (0.24)	0.26 (0.22)	-0.23	0.478
Holistic Perspective	0.36 (0.24)	0.31 (0.27)	0.83	0.434
Overall Score	0.36 (0.12)	0.33 (0.14)	1.02	0.607

Table 4

Independent Samples t-Test Results for Systems Thinking Skills Post-Test Scores

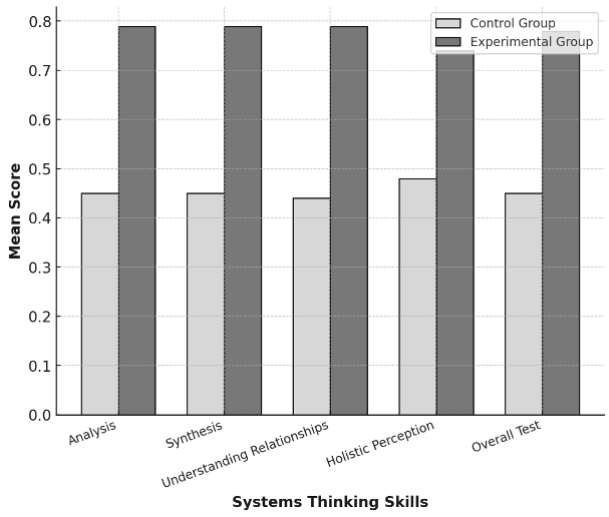
Systems Thinking Skills	Control Group (n = 33)		Experimental Group (n = 33)		t-value	p-value	Direction of Differences
	Mean	SD	Mean	SD			
Analysis	0.45	0.26	0.79	0.19	-6.16	< .001	Experimental
Synthesis	0.45	0.27	0.79	0.24	-5.46	< .001	Experimental
Understanding Relationships	0.44	0.28	0.79	0.18	-6.13	< .001	Experimental
Holistic Perception	0.48	0.27	0.74	0.25	-4.19	< .001	Experimental
Overall test	0.45	0.12	0.78	0.11	-11.67	< .001	Experimental

Note. t = t-value; p = p-value. Significance level: p < .05.

As shown in Table 4, the results revealed statistically significant differences in the post-test mean scores for systems thinking skills between the experimental and control groups, particularly in the skill of Understanding Relationships ($t(32) = -6.13$, $p < .05$). The overall t-value for systems thinking skills was -11.67, indicating a considerable difference favoring the experimental group. The mean scores for the control group ranged from 0.44 to 0.48, while the experimental group's mean scores ranged from 0.74 to 0.79. These findings suggest that STEM-based activities had a positive impact on students' systems thinking skills. Figure 1 illustrates the results.

Figure 1:

Mean Systems Thinking Skills Post-Test Scores for Experimental and Control Groups (N=66)



A paired samples t-test was conducted to compare pre-test and post-test scores for the experimental group across five domains and to test Hypothesis H1.2: At the $\alpha = 0.05$ level, there will be statistically significant differences between pre-test and post-test scores for the experimental group, favoring the post-test, thereby reflecting the impact of STEM-based activities. The results are presented in Table 5.

Table 5

Paired Samples T-Test Results for Pre- and Post-Tests

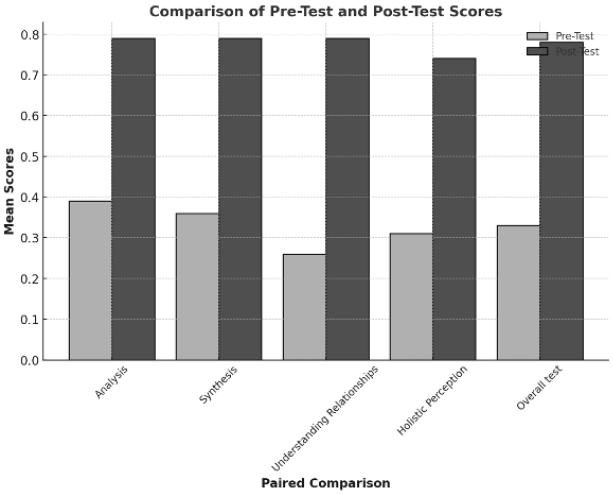
Paired Comparison	M (Difference)	SD	SE	95% CI (Lower)	95% CI (Upper)	t	df	p	Direction of Difference
Analysis	0.40	0.32	0.06	0.29	0.51	7.14	32	< .001	Post
Synthesis	0.43	0.34	0.06	0.31	0.55	7.28	32	< .001	Post
Understanding Relationships	0.53	0.28	0.05	0.43	0.63	10.71	32	< .001	Post
Holistic Perception	0.43	0.37	0.06	0.30	0.56	6.71	32	< .001	Post
Overall test	0.45	0.18	0.03	0.39	0.51	14.52	32	< .001	Post

Note. M = Mean Difference; SD = Standard Deviation; SE = Standard Error; CI = Confidence Interval; t = t-value; df = degrees of freedom; p = p-value. Significance level: p < .05.

The results indicated statistically significant improvements across all domains in the post-test compared to the pre-test. The largest mean difference was observed in "Understanding Relationships" ($M = 0.53$, $SD = 0.28$, $t(32) = 10.71$, $p < .001$), followed by "Overall test" ($M = 0.45$, $SD = 0.18$, $t(32) = 14.52$, $p < .001$). These findings suggest that the intervention had a positive impact on students' performance across all evaluated dimensions. Figure 2 illustrates the results.

Figure 2:

Mean Systems Thinking Skills Pre-Post-Test Scores for the Experimental Group



Discussion

This section analyses the study's findings in relation to existing research, highlighting key improvements in systems thinking skills and potential influencing factors. The results of this study indicate that STEM-based activities positively influenced the systems thinking skills of fourth-grade students, with statistically significant improvements across all assessed domains. Notably, the "Understanding Relationships" skill showed the greatest enhancement in the experimental group, highlighting its strong development through the intervention. This particular finding may be attributed to the nature of STEM-based activities, which inherently emphasize identifying patterns, connections, and interdependencies—core elements of understanding relationships within systems. Such activities often require students to observe how components interact, make predictions based on observed trends, and modify their solutions accordingly promoting a recursive process that nurtures relational and systems-oriented thinking. This outcome aligns with findings by researchers such as Abu Musa (2021), who suggests that because these approaches emphasize recognizing structural relationships within systems and developing mental models to address challenges, STEM approaches enhance complex cognitive skills, including those grounded in design thinking and systems analysis. Understanding relationships is a fundamental aspect of both problem-solving and model-building. In STEM tasks, learners move beyond rote procedures and are instead invited to think strategically—envisioning

dynamic systems, identifying feedback loops, and recognizing how modifying one variable can impact others. STEM-facilitated design thinking, which involves model-building, empathy, and iterative solution testing, fosters a level of advanced cognitive engagement that appears beneficial for developing skills related to recognizing and analyzing relationships within systems (Shahat et al., 2023).

Similarly, Darwish's (2024) study on spatial abilities and geometric thinking in STEM students supports the idea that STEM instruction is effective in fostering relational thinking skills, which are closely tied to understanding systems. While analytical thinking is also a key cognitive skill developed through STEM education, the primary focus here is on how STEM-based activities enhance students' ability to recognize connections, patterns, and interdependencies, reinforcing the improvements observed in the "Understanding Relationships" skill (see Figure 3).

Figure 3:
Example of students' work in the experimental group.

Moreover, the study's findings extend existing research by demonstrating that even at the elementary level, students can benefit cognitively from STEM experiences if activities are well-structured, appropriately scaffolded, and contextually meaningful. This has implications for the early introduction of systems thinking concepts, which are often reserved for older students. By embedding systems-based reasoning in younger learners' educational experiences, educators can cultivate foundational cognitive habits that support lifelong scientific literacy.

However, despite the overall statistically significant improvements across all domains in the post-test compared to the pre-test, several contextual factors may have limited the extent of skill development. The study was conducted during the second semester, coinciding with Ramadan, which resulted in a shortened instructional period and disruptions due to Eid holidays. Additionally, the school operated on a two-shift system, where lesson durations were reduced by 10 minutes (e.g., 45 minutes to 35 minutes), potentially limiting the depth and continuity required for students to engage with and internalize the STEM-based learning activities fully. This limited exposure may not have provided sufficient time for students to grasp the interconnected nature of STEM learning, particularly in ways that support the comprehensive development of systems thinking skills (Shahat & Al-Balushi, 2023).

The data supported the second hypothesis, which predicted significant differences between pre- and post-test scores favouring the experimental group. This finding aligns with prior research; for example Pertiwi et al. (2024) observed significant gains in critical thinking following a STEM intervention. Al-Enezi's (2020) study also noted similar findings, where STEM-based activities significantly improved problem-solving and academic achievement among intermediate students. These previous studies highlight the potential for STEM activities to provide a rich, integrative learning environment that fosters a variety of cognitive skills, especially when sufficient time and curricular flexibility are provided.

Beyond individual cognitive gains, these findings reinforce the broader educational value of STEM in supporting national and global goals related to 21st-century skills and the Fourth Industrial Revolution. Developing systems thinking skills through STEM education not only benefits academic performance but also prepares students for future challenges involving complex problem-solving, sustainability, and innovation (Al-Balushi et al., 2022; Abdurrahman et al., 2023). As such, STEM should not be viewed merely as a pedagogical trend, but as a strategic foundation for cultivating adaptive, systems-literate citizens.

The findings suggest that while STEM activities show promise in fostering systems thinking, factors such as instructional duration and curriculum structure may significantly influence their effectiveness. Future studies could be considered:

1. Extended interventions over multiple semesters allow for progressive development of systems thinking skills.

2. Adjustments to lesson duration, particularly in educational settings where STEM education is introduced in split-shift schedules or during condensed academic periods.

3. A more integrated STEM curriculum, ensuring that students have ample time to engage with hands-on learning experiences and develop higher-order cognitive skills (Shahat et al., 2024c).

Additionally, qualitative follow-up studies could explore how students conceptualize system interactions during STEM tasks, providing richer insights into cognitive processes that standardized tests may overlook. Investigating teacher implementation practices and student engagement patterns could also help refine future program design.

Such modifications may yield a more comprehensive development of systems thinking skills, better reflecting the full potential of STEM-based learning and its impact on student cognition.

Limitations

One limitation of this study was the sample size and scope, as it was conducted in a single school with two fourth-grade classes. While the study provides valuable insights, the findings may not be fully generalizable to broader educational contexts. A larger sample, encompassing multiple schools with varied instructional settings, would offer a more comprehensive understanding of how STEM-based learning influences systems thinking skills in different learning environments.

A second limitation relates to the duration and structure of instructional time. The intervention was conducted during the second semester, which coincided with the holy month of Ramadan and the Eid holidays. As a result, the available teaching time was compressed. Moreover, the school's two-shift schedule reduced the standard lesson duration to just 10 minutes. These time constraints may have restricted students' opportunities for deep engagement with the STEM activities, particularly those requiring iterative exploration and extended model-building—both essential for developing systems thinking.

Another important consideration is the potential influence of the classroom teacher. Although efforts were made to standardize instruction across both the control and experimental groups, variations in teacher experience, enthusiasm, or familiarity with STEM practices may have influenced implementation fidelity and student responsiveness. Future studies should consider either using multiple teachers to dilute individual influence or employing video monitoring and fidelity checklists to ensure consistent delivery.

In addition, external environmental factors—such as classroom resources, parental support, and students' prior exposure to inquiry-based learning—may have acted as confounding variables, despite efforts to maintain equivalency between groups. These factors were not measured in this study but could have had an indirect effect on students' ability to benefit from the intervention.

Implications

Despite its limitations, this study highlights the potential of STEM-based activities in enhancing systems thinking skills among elementary students—particularly in recognizing relationships within systems. To support practical application in educational contexts, the following implications are offered:

- Integrate STEM into the elementary curriculum to promote early development of cognitive skills such as problem-solving, analysis, and relational thinking. These skills form the foundation for more complex learning in higher grades and across disciplines.
- Design STEM activities that emphasize identifying and analyzing relationships within complex structures. Such focus helps students develop transferable systems thinking abilities applicable to science, mathematics, and beyond.
- Ensure sufficient instructional time for STEM lessons. Where possible, adopt flexible or extended periods to allow deep engagement with STEM tasks. If longer periods are not feasible, strategically structure shorter lessons to retain core inquiry and reflection components.
- Consider scheduling and classroom conditions as critical factors in implementation. Reduced lesson times and two-shift systems can limit the depth of student interaction with STEM content, thus requiring thoughtful instructional design.
- Promote a holistic and interdisciplinary learning environment where students are encouraged to make connections across scientific and mathematical concepts. This helps cultivate systems thinking as a long-term competency from early education stages.

By addressing these instructional and structural factors, educators and curriculum designers can optimize the integration of STEM-based education to enhance students' systems thinking and equip them for future academic and real-world challenges.

Future Directions

Building on the findings of this study, future research should consider extending the duration of STEM interventions over multiple semesters to provide students with continuous exposure, allowing for the progressive and comprehensive development of systems thinking skills. A longer intervention period would enable students to reinforce and internalize STEM concepts more effectively, supporting deeper cognitive engagement and the gradual mastery of complex problem-solving processes (Shahat, Al-Balushi, & Al-Amri, 2023). Given that STEM education fosters engineering design thinking and cognitive flexibility, extended exposure may lead to more sustainable cognitive development in systems

thinking-related skills (Shahat et al., 2024a).

Further studies should explore STEM integration in diverse educational models, including those with flexible or extended lesson times, to determine the optimal instructional conditions for fostering systems thinking skills. Investigating how different teaching structures, such as block scheduling or inquiry-based learning models, impact STEM learning outcomes would provide valuable insights for curriculum design (Shahat & Al-Balushi, 2023). Additionally, expanding the sample size and including schools with varied instructional settings—such as those operating on single-shift versus two-shift systems—could enhance the generalizability of the findings and help identify specific factors that contribute to successful STEM implementation across different learning environments (Shahat, Al-Balushi, & Al-Amri, 2024b).

Moreover, future research should broaden the scope to explore the impact of STEM activities on other essential cognitive skills, such as critical thinking, creativity, and problem-solving. Studies have shown that STEM-based learning enhances students' ability to think critically and innovate solutions to real-world challenges (Shahat et al., 2024c). Since STEM education emphasizes interdisciplinary thinking and practical applications, it is crucial to investigate how these approaches contribute to students' ability to synthesize information and apply knowledge across different disciplines (Shahat et al., 2024d).

Longitudinal studies could provide valuable insights into the long-term effects of early STEM exposure on students' academic trajectories, particularly in science, technology, engineering, and mathematics disciplines. Tracking students over several years would help determine how early engagement in STEM influences future academic performance, career interests, and STEM-related professional pathways (Shahat et al., 2024e). Additionally, examining gender differences in STEM learning outcomes could provide critical perspectives on how to provide equitable STEM education opportunities for all students (Al-Balushi et al., 2022).

Lastly, future research could investigate the role of teacher training in enhancing the effectiveness of STEM interventions. Understanding how educators' expertise, instructional strategies, and professional development programs influence STEM implementation could inform policies aimed at strengthening STEM education at both the classroom and institutional levels (Shahat et al., 2023). Studies emphasize the importance of teacher preparation programs in equipping educators with the skills necessary for effectively implementing STEM-based learning (Shahat et al., 2024a). By addressing these research areas, future studies can contribute to the continuous improvement of STEM education, ensuring that it effectively supports students' cognitive and professional growth in an increasingly technology-driven world.

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