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Front Pages

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The **Athens Journal of Education** (AJE) is an Open Access quarterly double-blind peer reviewed journal and considers papers from all areas of history. Many of the papers published in this journal have been presented at the various conferences sponsored by the Education Unit of the Athens Institute. All papers are subject to Athens Institute's Publication Ethical Policy and Statement.

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Athens Journal of Education
Editorial and Reviewers' Board

President's Message

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The current issue is the third of the twelfth volume of the *Athens Journal of Education (AJE), published by the Education Unit of Athens Institute.*

Gregory T. Papanikos
President
Athens Institute

Athens Institute for Education and Research

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18-21 May 2026, Athens, Greece

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- **Dr. Nick Linardopoulos**, Head, Education Unit, Athens Institute & Associate Teaching Professor & Public Speaking Course Coordinator, Rutgers University, USA.
- **Dr. John Spiridakis**, Co-Editor, Athens Journal of Education & Professor, St. John University, USA.

Important Dates

- Abstract Submission: **14 October 2025**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **20 April 2026**

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- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **9 June 2025**

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- **Dr. David Philip Wick**, Director, Arts, Humanities and Education Division, Athens Institute & Professor of History, Gordon College, USA.
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Cultivating Positive Teacher-student Relationships: Effects of Tailored Positive Behavior Support Interventions on Classroom Discipline

By Rene Martinez[*], Mervyn Wighting[±] & Marissa Ash[°]

This research study examined the effect of positive behavioral interventions and supports (PBIS) on the nature of student-teacher relationships, emphasizing classroom behavior dynamics. The study evaluated the connections between students in grades preK-12 and their teachers in a southeastern state in the USA, focusing on the implementation of positive behavior support strategies. The research utilized a methodology involving pre- and post-surveys along with a two-week application of chosen positive behavior interventions, particularly targeting students with prior discipline referrals. The central research question investigated the influence of a short-term positive behavioral support intervention on student-teacher relationships, specifically among students with a history of discipline referrals.

Keywords: school discipline, teacher-student relationships, students' behavior, PBIS, teacher preparation.

Introduction

In recent years, fostering positive student-teacher relationships in a K-12 environment has become increasingly recognized as a crucial element in creating a supportive and conducive learning environment. Positive Behavioral Interventions and Supports (PBIS) have emerged as a promising framework to enhance these relationships by providing strategies to address behavioral challenges and promote positive interactions. This research paper examines the effectiveness of PBIS in improving student-teacher relationships through quantitative analyses on closeness and conflict and explores the impact of different PBIS methods. By investigating the outcomes of PBIS interventions, this study aims to provide insights for educators and school leaders to optimize behavior support strategies and to cultivate harmonious student-teacher relationships in classroom settings. The study builds on a line of research by the authors (Martinez, R. and Wighting, M.J. 2022, 2021), and its focus is on students who have received referrals for discipline infractions.

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Review of the Literature

Teacher-Student Relationships

Existing research underscores the crucial role of positive teacher-student relationships in academic achievement and student well-being. Studies have highlighted increased student engagement, motivation, and self-esteem as outcomes of supportive relationships with teachers. Notably, the quality of these relationships is linked to positive behavior and a conducive learning environment (Roorda et al., 2011; Hamre & Pianta, 2001). Students' interactions and subsequent relationships with teachers are paramount for their emotional regulation, attention, problem solving, and subsequently their academic achievement (Pianta, 2006). A study conducted in the two different curriculum areas of math and physical education (Jowett et al., 2023) found that teacher-student relationships have a strong impact on academic engagement and progress and that students whose relationships with their teachers are of high quality are more likely to experience positive affect, enjoyment, and intrinsic motivation, as well as higher levels of physical self-concept and perceived competence. Conversely, a study conducted on the effects of the Covid-19 pandemic on teacher-student relationships (Farris et al., 2023), reported that the rapid change from in-person to remote learning led to turbulence and turmoil in relationships leading to a negative effect on the promotion of academic goals. In a synthesis of the relevant literature, Dai (2024) concluded that a positive teacher-student relationship can not only improve students' classroom participation and act as an intermediary to regulate students' emotions, but also cultivate students' learning skills and help students to achieve their learning goals and achievements.

Impact of PBIS on Student Behavior

Several research studies have reported on the impact of PBIS on student behavior. A study by Wienen et al. (2019) was conducted to determine how teachers perceive the impact of PBIS on student behavior and concluded that teachers found PBIS to be more effective in managing girls' behavior than behavior by boys. It also found that PBIS had greater impact in general educational settings compared to classrooms with special needs children. Lawrence et al. (2022) conducted a study to obtain perspectives from teachers who had implemented PBIS. The teachers reported that PBIS had a positive impact on student behavior, and reported also that PBIS helped them to use more effective classroom management strategies. Noltemeyer et al. (2019) investigated the impact PBIS had on student achievement and behavior in classroom settings in elementary and middle schools. The purpose of the study was to determine if the implementation of PBIS had a positive impact on the way students behave in class as well as the academic performance of students. The researchers concluded that there was a positive connection between the implementation of PBIS and student behavior, revealing a significant decline in student misbehavior, office referrals, and school suspensions. Pas et al. (2019) also conducted a study to investigate the impact that PBIS had on student behavior and academic performance. The participants in this study were students from elementary, middle, and high school.

The study's results indicated that PBIS positively impacted student behavior as evidenced by decreased office referrals and suspensions. Additionally, the research revealed that PBIS had a positive impact on student achievement. Elrod et al. (2020) conducted a mixed methods research study to investigate the impact that PBIS had on school climate and student discipline. To gather qualitative data, the 24 researchers interviewed over 2,000 middle and high school students. The researchers reviewed quantitative data from office referrals compared to data collected before PBIS was implemented and collected qualitative data by interviewing students. The results of this study indicate that PBIS positively impacted both the school climate and the rate of student misbehavior.

The studies reviewed above examined the effects of PBIS on behavior exhibited by a broad spectrum of students. Fortune-Williams (2023) studied the effects of PBIS on students who were already identified as having behavior issues and had been placed on a Behavior Intervention Plan by their school. The results of this study were that most of the teachers interviewed felt that PBIS is effective for children with behavior issues because the intervention acts as a motivational tool, gives students something to work towards, decreases negative behaviors, and increases positive behaviors. Additionally, the study indicates that teachers believe PBIS effectively reduces behavior infractions in the classroom.

This current research also investigates the impact of PBIS on teacher-student relations by studying children who have been identified as having behavior challenges as evidenced by office referrals.

Research Question

How does the implementation of a positive behavioral support intervention for two weeks affect student-teacher relationships, particularly with students who have had discipline referrals?

Method

The study employed a quantitative approach involving 44 classroom teachers to evaluate the impact of positive behavioral interventions and supports (PBIS) on student-teacher relationships, focusing on 195 students in grades preK-12. Utilizing the Student-Teacher Relationship Scale (Pianta, 2001), participants in the study were tasked with selecting a suitable PBIS strategy from an array of options - individual conversations, written feedback, verbal praise, immediate rewards, or granting material privileges for a two-week intervention.

Participants

All participating teachers are employed teaching children in grades preK-12. The largest percentage of teachers teach in middle school, 63% (grades 6-8); 21% of the teachers teach pre-K through grade 2; 11% of the teachers teach in grades 3-5; and 6% of the teachers teach in high school (grades 9-12). When teachers

completed the survey, they purposefully selected three to five students in their class to take part in the study. The students chosen are students with behavioral concerns; whether they had a written office referral or if the teacher had to address a concern beyond gentle reminders in class. Data were collected on a total of 195 students. After implementing a two-week positive behavioral support intervention, teachers completed a post-survey with the same students. All participants were teaching in the same state within the USA.

Instrument

The teachers' perceptions of the quality of their relationships with the students they teach were assessed using the short form of the Student-Teacher Relationship Scale (STRS), developed by Pianta in 2001. This 15-question survey is a reliable and valid teacher-reported standardized instrument designed to measure the quality of relationships between teachers and students. An example of this instrument can be found in Appendix A of the study.

During the survey, teachers were asked to respond to all items using a 5-point Likert-type scale, where 1 indicated "definitely does not apply" and 5 indicated "definitely applies." Following the completion of the initial survey, teachers selected a positive behavior support intervention to implement for a two-week period. At the end of that period, teachers filled out a post-survey using the same instrument to evaluate any changes in their perceptions of the quality of relationships with their students after implementing the PBIS.

Upon selection, the participants implemented their chosen PBIS strategies over a two-week period. The choices made available to the teachers were:

1. Daily 2-Minute Conversations: Teachers conversed with students for 2 minutes each day.
2. Written Feedback: Teachers provided written feedback in individual student daily journals.
3. Verbal Praise: Teachers offered verbal praise for good behavior.
4. Immediate Rewards: Teachers provided immediate rewards (e.g., food, candy).

To measure the changes in the relationships between students and teachers, pre- and post-intervention surveys were administered using the STRS and focusing specifically on the Closeness and Conflict subscales of the STRS which are listed in Appendix A.

Results

Analysis 1: Closeness versus Conflict (from the STRS)

This analysis examined how a two-week positive behavior intervention strategy impacted student-teacher relationships, especially for students with a history of discipline referrals. A paired samples t-test was used to compare scores from

before and after the intervention on the Closeness and Conflict subscales of the STRS. Key Findings are shown in Figure 1 below.

Figure 1. *Boxplots Depicting Pre- and Post-test Results for Closeness and Conflict Items*

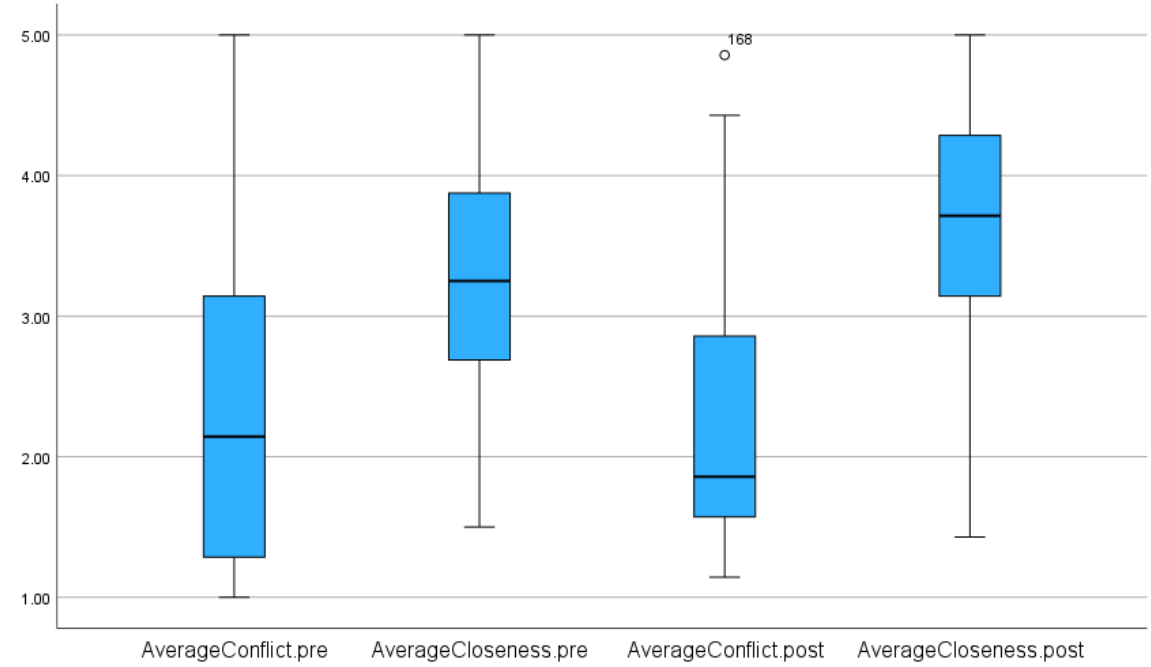

Figure 1 shows the three key aspects of student-teacher relationships following an intervention. Firstly, there was significant improvement in closeness between students and teachers. Before the intervention, the average pre-test closeness score was 3.24, which increased to 3.59 in the post-test. This increase in closeness was statistically significant ($p < .001$) with an effect size of 0.50, suggesting a meaningful enhancement in students' perceived closeness to their teacher's post-intervention. Secondly, it shows a reduction in conflict. Initially, the average pre-test conflict score was 2.37, which decreased to 2.20 in the post-test. This reduction in conflict was statistically significant, with an effect size of 0.23, indicating a noticeable decrease in conflicts between students and teachers following the intervention. Lastly, the study found consistency in the distribution of 5-point Likert ratings for both closeness and conflict before and after the intervention. This overlap in ratings suggests that students provided similar assessments of closeness and conflict levels, indicating stability in their perceptions throughout the study. This consistency implies that the changes observed were due to the intervention.

Overall, these results indicate that the PBIS intervention significantly improved student-teacher relationships by increasing closeness and reducing conflict. This was particularly beneficial for students with a history of discipline referrals.

Analysis 2: Results by PBIS Method

In this analysis, a one-way between-subjects multivariate analysis of variance (MANOVA) was used to study the impact of different PBIS methods on student-teacher relationships with students having a history of discipline issues. The four PBIS methods available to participants were examined. A fifth method, granting material privileges (e.g., cell phone use), was considered but was excluded from the analysis due to extreme outliers and a small sample size. Table 1 presents the means and standard deviations of the dependent variables for the four PBIS groups.

Table 1. Descriptive Statistics with the Means and Standard Deviations on the Dependent Variables for the Four PBIS Method Groups

Student-Teacher Relationships	PBIS Method	Mean	Std. Deviation	*N*
Closeness	Converse with Student Daily	3.7233	.66824	79
	Written Feedback in Daily Journals	3.0000	.76931	9
	Verbal Praise for Good Behavior	3.5044	.79384	49
	Provide Immediate Reward	3.5758	.73755	33
	Total	3.5954	.72472	170
Conflict	Converse with Student Daily	2.1917	.86242	79
	Written Feedback in Daily Journals	1.9683	.86242	9
	Verbal Praise for Good Behavior	2.1983	.94303	49
	Provide Immediate Reward	2.2381	.94130	33
	Total	2.2027	.88890	170

The descriptive statistics, as presented in Table 1, show the means and standard deviations for, and conflict ratings between, students and teachers across each PBIS method group.

Subsequently, the results of the MANOVA revealed no statistically significant effect of the PBIS methods on student-teacher relationships; specifically, the Pillai's trace value at 0.07, $F(6, 332) = 1.89$, $p = .08$, with a partial eta squared (η_p^2) value of .03. This indicates a small effect size suggesting minimal impact across the four intervention groups. These results are further summarized in Table 2.

Table 2. Multivariate Tests[a] for PBIS Method

Effect	Test	Value	*F*	Hypothesis *df*	Error *df*	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.953	1669.760[b]	2.000	165.000	<.001	.953
	Wilks' Lambda	.047	1669.760[b]	2.000	165.000	<.001	.953
	Hotelling's Trace	20.240	1669.760[b]	2.000	165.000	<.001	.953
	Roy's Largest Root	20.240	1669.760[b]	2.000	165.000	<.001	.953
PBIS Method	Pillai's Trace	.066	1.881	6.000	332.000	.083	.033
	Wilks' Lambda	.934	1.899[b]	6.000	330.000	.080	.033
	Hotelling's Trace	.070	1.917	6.000	328.000	.077	.034
	Roy's Largest Root	.068	3.789[c]	3.000	166.000	.012	.064

a. Design: Intercept + PBIS Method
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Despite the nonsignificant overall MANOVA, further post hoc univariate ANOVAs indicated that differences in student-teacher relationships by PBIS Method were statistically significant for Closeness. Specifically, there was a significant effect for Closeness, $F(3, 166) = 3.11$, $\eta_p^2 = .05$, $p = .03$, indicating a small effect size. In contrast, differences concerning conflict ratings were not statistically significant, $F(3, 166) = .21$, $\eta_p^2 = .004$, $p = .89$. Details regarding these findings are presented in Table 3.

Table 3. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	Closeness	4.901[a]	3	1.634	3.109	.028	.053	9.328	.717
	Conflict	.522[b]	3	.174	.214	.887	.004	.642	.090
Intercept	Closeness	1092.016	1	1092.016	2078.323	<.001	.926	2078.323	1.000
	Conflict	423.522	1	423.522	520.356	<.001	.758	520.356	1.000
PBIS Method	Closeness	4.901	3	1.634	3.109	.028	.053	9.328	.717
	Conflict	.522	3	.174	.214	.887	.004	.642	.090
Error	Closeness	87.222	166	.525					
	Conflict	135.109	166	.814					
Total	Closeness	2287.102	170						
	Conflict	951.538	170						
Corrected Total	Closeness	92.123	169						
	Conflict	135.631	169						

a. R Squared = .053 (Adjusted R Squared = .036)
b. R Squared = .004 (Adjusted R Squared = -.014)
c. Computed using alpha = .05

The analysis of the follow-up ANOVAs revealed significant differences among the PBIS methods. Notably, Method 2 (written feedback) was associated with significantly lower scores on Closeness compared to other groups. Conversely, Method 1 (daily conversations) showed a statistically significant improvement in student-teacher relationships compared to Method 2, with a mean difference of 0.72, p = .03.

In conclusion, this analysis underscores the significance of selecting appropriate PBIS strategies to enhance student-teacher relationships. Among the methods examined, daily conversations (Method 1) emerged as the most effective approach, highlighting the necessity for educators to adopt tailored approaches to foster positive student-teacher interactions.

Discussion

Despite the expectation that different PBIS methods would yield significant effects on student-teacher relationships, the overall MANOVA results indicated nonsignificant findings. However, it is important to recognize that follow-up ANOVAs revealed significant differences in the context of Closeness, specifically highlighting that Method 1 (daily conversations) was statistically significantly more effective than Method 2 (written feedback), with a mean difference of 0.72, p = .03. This distinction underscores the importance of exploring factors that may

have influenced the overall nonsignificant findings while acknowledging the significant effects present in specific contexts.

One potential reason for the nonsignificant results in the broader analysis could be the variability in implementation fidelity among the different PBIS methods. If teachers applied the methods with differing levels of consistency and adherence, this inconsistency could dilute the observable effects of the interventions across the entire sample. For instance, some teachers may have effectively engaged in daily conversations (Method 1) to build relationships consistently, while others utilizing written feedback (Method 2) may have done so sporadically or with less enthusiasm. This variability in application can lead to an overall nonsignificant result despite the identified effectiveness of Method 1 for enhancing Closeness.

Additionally, inherent student characteristics may have contributed to the nonsignificant findings in the overall analysis. Students with a history of discipline issues exhibit a wide range of personal characteristics, such as varying levels of motivation, resilience, and existing relationships with teachers. These individual differences can obscure the effects of PBIS methods when considered collectively. For example, a student who consistently struggles with academic and behavioral issues might respond differently to verbal praise (Method 3) compared to a student with a more stable academic history. This variance in response could lead to overall insignificant results, despite the notable effectiveness of daily conversations (Method 1) in fostering stronger student-teacher relationships.

Furthermore, the sample size and distribution among the different PBIS methods also play a crucial role in interpreting the nonsignificant findings. With a limited representation and an unequal number of participants across the methods (as shown in Table 1), the statistical analysis's power may have been reduced. This limitation implies that while Method 1 yielded significant results in enhancing Closeness, the overall effects across all methods might not have been adequately captured due to insufficient sample size and variance in the application of the PBIS strategies.

In summary, while the absence of significant overall findings may suggest that PBIS methods, in general, do not affect student-teacher relationships, it is essential to consider factors such as implementation fidelity, student characteristics, and sample size limitations. Importantly, Method 1's significant effectiveness in enhancing Closeness indicates that under specific conditions, certain PBIS strategies can indeed improve student-teacher relationships. Understanding these dynamics can inform future research and practice in educational settings and guide educators in selecting and implementing the most effective PBIS strategies tailored to their specific contexts.

Implications

The findings of this research have significant implications for educational practices and future studies regarding Positive Behavioral Interventions and Supports (PBIS), particularly concerning student-teacher relationships. The notable effectiveness of daily conversations (Method 1) in enhancing Closeness underscores the importance of prioritizing and implementing strategies that foster direct, personal interactions with students. This insight reinforces the value of building strong

relationships through consistent communication and encourages educators to employ practices that facilitate meaningful engagement.

Furthermore, the variability observed in the application of different PBIS methods highlights the critical need for professional development programs focused on implementation fidelity. Educators must be equipped with the necessary skills and knowledge to apply these interventions consistently to achieve desired outcomes. Schools should also develop structured guidelines and provide ongoing support to ensure all staff members can effectively implement PBIS strategies. For school administrators, the findings offer several key implications. Principals can leverage this study's results to support and encourage the implementation of PBIS within their schools, particularly emphasizing the need to tailor strategies for diverse student populations. Additionally, they should facilitate professional development opportunities for teachers to enhance their understanding and practice of effective PBIS methods, ultimately empowering them to advocate for resources and support systems that foster positive student-teacher relationships and address behavioral challenges effectively.

Teachers, as well, should take note of critical points highlighted by this study. The effectiveness of the two-week positive behavior intervention strategy in improving student-teacher relationships—especially for students with past discipline issues—demonstrates that short-term, targeted interventions can lead to meaningful, positive changes. Among the PBIS methods analyzed, daily conversations emerged as the most effective strategy for enhancing these relationships, confirming that consistent personal interaction is vital for building strong connections with students. Additionally, collaboration with colleagues to share best practices and insights can further enrich the implementation of PBIS methods that enhance student behavior and engagement.

The findings also suggest a need for further research to explore how various student characteristics, such as motivation, resilience, and prior academic performance, impact responses to PBIS methods. Gaining insights into these relationships can inform more responsive interventions that cater to individual student needs, ultimately leading to more effective approaches for enhancing student-teacher relationships.

These findings can also inform district and school-level policies by emphasizing the need for strategies that promote positive student-teacher interactions. Policymakers should consider the outcomes associated with effective PBIS methods when designing frameworks to support educators and address the diverse needs of students. Finally, given the importance of Method 1 in improving Closeness, schools should consider initiatives that promote relational strategies. Integrating activities, workshops, or programs that encourage meaningful student-teacher interactions into the school curriculum can help create an environment that prioritizes strong relationships.

In conclusion, this research provides valuable insights into the impact of various PBIS methods on student-teacher relationships, indicating that specific approaches can yield significant benefits. By focusing on tailored practices, enhancing implementation fidelity, and understanding student diversity, educators and researchers can enhance the effectiveness of PBIS interventions, ultimately leading to improved outcomes in student behavior and academic achievement.

Recommendations

Administrators are encouraged to support and implement PBIS strategies, provide professional development for teachers, and to advocate for necessary resources. It is recommended that administrators encourage their staff to employ PBIS methods that involve personal interaction, such as daily conversations, to foster closeness and reduce conflict with students.

Teachers are recommended to utilize short-term, targeted PBIS interventions with daily conversations to foster strong student-teacher relationships, and to collaborate with colleagues on best practices for implementing PBIS. Improved teacher-student relationships may be particularly beneficial for students who have received discipline referrals. Teachers should evaluate and subsequently adapt PBIS strategies so that they are tailored for their classrooms.

Students will benefit from improved relationships that may result from PBIS, and it is recommended they be encouraged to participate actively in behavior support and the development of self-regulation skills.

Conclusion

This research underscores the significant impact of Positive Behavioral Interventions and Supports (PBIS) on student-teacher relationships. The analysis demonstrated a notable improvement in relationships following the intervention, particularly in terms of increased closeness and reduced conflict, validating the effectiveness of PBIS in fostering positive interactions. The evaluation of various PBIS methods revealed diverse impacts, highlighting the necessity for tailored strategies to meet the unique needs of different student populations.

The study highlights the importance of personalized PBIS strategies in enhancing student-teacher relationships and stresses the need for ongoing refinement of these methods. By implementing these findings, educators can create more positive classroom environments that support student success and well-being.

Recommendations for Future Research

- Create a longitudinal study to track the sustained effects of PBIS on student-teacher relationships over an extended period, assessing long-term outcomes and effectiveness.
- Compare the effectiveness of PBIS methods across different school settings or educational levels to identify the most impactful strategies for enhancing student-teacher relationships.
- Conduct mixed-method research incorporating qualitative sections, e.g. interviews or focus groups, to gain a deeper understanding of the experiences and perceptions of teachers, students, and parents regarding PBIS strategies and their impact on relationships.

- Initiate a study to investigate tailoring PBIS interventions to individual student needs and characteristics to determine the most effective and personalized approaches for behavior support.
- Examine the influence of specific teacher preparation programs related to PBIS on the implementation of behavior support strategies and their impact on student-teacher relationships.
- Explore additional behavioral outcomes beyond closeness and conflict in student-teacher relationships, such as academic performance, attendance, and overall well-being, to provide a comprehensive assessment of PBIS effectiveness.

By exploring these avenues of research, educators and administrators may better understand and optimize PBIS strategies to foster stronger, more supportive student-teacher relationships, ultimately enhancing the educational experience and outcomes for students.

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Appendix A. Student-Teacher Relationship Scale (STRS)

Subscale (Conflict or Closeness)	**Question**
closeness	1. I share an affectionate, warm relationship with this child.
conflict	2. This child and I always seem to be struggling with each other.
closeness	3. If upset, this child will seek comfort from me.
closeness	4. This child is uncomfortable with physical affection or touch from me.
closeness	5. This child values his/her relationship with me.
closeness	6. When I praise this child, he/she beams with pride.
closeness	7. This child spontaneously shares information about himself/ herself.
conflict	8. This child easily becomes angry with me.
closeness	9. It is easy to be in tune with what this child is feeling.
conflict	10. This child remains angry or is resistant after being disciplined.
conflict	11. Dealing with this child drains my energy.
conflict	12. When this child is in a bad mood, I know we're in for a long and difficult day.
conflict	13. This child's feelings toward me can be unpredictable or can change suddenly.
conflict	14. This child is sneaky or manipulative with me.
closeness	15. This child openly shares his/her feelings and experiences with me.

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Important Aspects of Teacher Shortage in Schools. A Literature Review

By Marcia Håkansson Lindqvist[*] & Ulrika Gidlund[±]

Teacher shortage is reported to be a challenge worldwide. In a recent report, United Nations Educational, Scientific and Cultural Organization (UNESCO) reported the need for some 44 million new teachers in schools to reach the Agenda 2030 targets. Attracting, recruiting and retaining new teachers is difficult in relation to both geographical areas and in certain subjects, being a common challenge of many developed countries and is seen in many countries of the world. Teacher shortage and the lack of teachers has consequences as teaching in schools, students' learning and therefore the quality of education is affected. The aim of this paper was to study teacher shortage in schools through a literature review in order to explore the causes of the teacher shortage described in current literature and understand these causes based on teacher attrition, teacher recruitment and teacher retention. The included articles of this literature review were peer-reviewed articles regarding teacher shortage from 2018-2023 which were identified using the Scopus database. Some 52 of articles met the inclusion criteria of this literature review. The articles represented 18 different countries all over the world. The chosen methods of the studies also varied, for example, qualitative and quantitative studies. The content of the included articles was thematically encoded and categorized by the described a) reasons behind, b) area/subject c) and discussed solutions. The themes were identified inductively; they were strongly linked to the data, and the steps of qualitative content analysis were followed to identify these themes. The overall conclusion is that teacher shortage is multifaceted and complex. There are many reasons behind teacher shortage and there are many aspects that interact on several different levels. In order to alleviate teacher attrition and promote teacher recruitment and retention, collective initiatives by many of the stakeholders involved will be necessary.

Keywords: Professional development, qualitative content analysis, research review, teachers, teacher shortage

Introduction

Teacher shortage appears to be a challenge worldwide. In a recent report, United Nations Educational, Scientific and Cultural Organization UNESCO reports the need for some 44 million new teachers in schools to reach the Agenda 2030 targets (UNESCO, 2024). Attracting and retaining new teachers is difficult in relation to both geographical areas and in certain subject areas. Teacher shortage is a common challenge for many developed countries (European Commission, 2018). Teacher shortage is seen in many countries (Federičová, 2020; Håkansson

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Lindqvist, Boström & Gidlund, 2022; O'Doherty & Harford, 2018). Teacher shortage has consequences as teaching in schools, students' learning and therefore the quality of education. For example, UNESCO (2024) reports on the effects of teacher shortage on achieving the Sustainable Development Goal (SDG) 4 in Education.

Aim and Research Questions

The aim of this paper is to study teacher shortage in schools through conducting a literature review in order to analyse peer-reviewed articles regarding teacher shortage from the period of 2018-2023. The following questions were posed: 1) How are the causes of the teacher shortage described in current literature? and 2) How do the reasons that have emerged for teacher shortage give an understanding of teacher attrition, teacher recruitment and teacher retention? This paper reviews teacher shortage and possibilities to alleviate teacher attrition, and to promote teacher recruitment and retainment. This involves attracting more people into teaching and keeping them in the profession by identifying the proposed solutions to teacher shortage. Acknowledging that the educational systems differ greatly from each other, this paper contributes to previous research on teacher shortage, as proposed solutions to teacher shortage is essential knowledge so that political and policy initiatives can effectively strive towards solutions of the current issue of teacher shortage internationally.

Background

Teacher shortage is not only a national issue in specific countries. The current shortages are to be seen in many countries, but it differs from country to country, area to area, and of different subject areas, which has been announced in several countries (European Commission, 2015; Eurydice, 2018). The shortage is predicted to get worse as the student population increases, less students go into teacher training, or more qualified teachers leave the teaching career. These shortages are often named to depend on the relatively low pay of teachers (Dee & Goldhaber 2017; Aldeman 2015; Ingersoll 2011; Hutchings 2011; Dolton, Tremayne, & Chung 2003). Further low status, poor career opportunities and heavy workloads in schools (Borman & Dowling 2017; Hayes 2017; Hobson, Giannakaki, & Chambers 2009) are also important aspects which have impact on teacher shortage.

Although teacher shortage is currently discussed immensely, these shortages are not new. There has been reported a shortage in specific subject areas, such as math and science, since at least the 1950s, and in special education there has been a continual shortage since the 1960s (Ingersoll & Perda, 2010; U.S. Department of Education Office of Postsecondary Education, 2017).

Teacher shortage is particularly urgent in subject areas such as Science, Technology, Engineering, and Mathematics (STEM). Special Education Needs (SEN), and bilingual education (Darling-Hammond et al., 2018). The same is

reported high-poverty and high-minority areas, such as high-risk inner cities schools or schools in rural areas (Loeb, Darling-Hammond, & Luczak, 2005; Darling-Hammond, 2010; Adamson & Darling-Hammond, 2012).

Other areas reported for teacher shortage are teachers of ethnic minority and their gender (Aldeman, 2015; Dee & Goldhaber, 2017). Reported in the US, but also seen in the rest of the world, are schools where the majority of students are of colour, such as Black, Hispanic, and Asian, the majority of the teachers are not of the race/ethnicity as the majority of students (NCES, 2020) which involves an imbalance for students.

Furthermore, teaching appears to be less attractive to males than females. The teaching profession has been reported as one of the most gender-segregated professions among the countries participated in the Teaching and Learning International Survey (TALIS) in 2012 (OECD, 2014). Thus, in regard to teacher shortage, the gender issue may also involve a challenge.

Methodology/Materials and Methods

Descriptive research synthesis relies on explicit search strategies and on unambiguous criteria for selecting pertinent, high-quality studies. It is systematic, explicit, comprehensive, and reproducible, and it relies on knowledge, evidence, and experience to identify and interpret similarities and differences in the studies' purposes, methods, and findings (Fink 2005).

Identification

This literature review involved a research synthesis in multiple phases to identify the studies dealing with the research questions, and the recommendation of PRISMA statements were followed (PRISMA, 2020). An initial identification of potential studies was conducted via an advanced keyword search of the SCOPUS database in September 2023, regarding teacher shortage from 2018-2023. SCOPUS was chosen because it is the world's largest abstract and citation database of peer-reviewed research literature (Elsevier, 2023) with over 7,000 publishers and includes more than 91 million records, and 17 million authors from different countries. Firstly, a broad search using the keywords from the research questions was used to establish the main outline of the study. Only English-language, peer-reviewed articles from the social sciences were included. This broad search resulted in too many articles (94), which led to a series of more detailed searches, starting with an initial sorting on the titles and keywords of the articles found in the broad search.

The key words, and their thesaurus terms, used for each search were: *"Teacher Shortage/s"; "Teacher Recruitment"; "Teacher Retention"* and *"Teacher Attrition"*.

Screening

The combination of the terms "Teacher Shortage/s" resulted in 42 sources; "Teacher Recruitment" resulted in 18 sources; "Teacher Retention" resulted in 13

sources; "Teacher Attrition" resulted in 8 sources; and "Teacher Education" and "Teacher Preparation" resulted in 12 sources. To determine whether the studies' findings were comparable and compatible, the following inclusion criteria were used in the study: 1) the article focused on teacher shortage, and 2) contained empirical data.

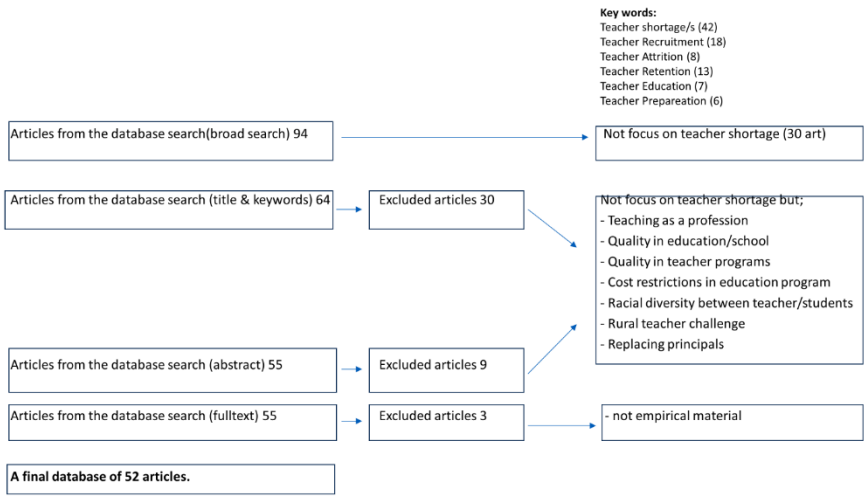
The broad search returned 93 articles. After reading the titles and keywords, 30 articles were rejected because they did not focus specifically on teacher shortage. For example, these articles placed focus on teaching as a profession, quality in schools or school leaders' work which could considered to be out of scope for this literature review.

Eligibility

After this first filtering, some 64 articles remained, and after an additional abstract screening it led to a database of 55 articles. Articles on other areas than teacher shortage and those articles which focused on how to work with efficient specific subjects, or teacher programs were excluded. For this literature review, articles were included only if they dealt with teacher shortage specifically.

After reading the articles carefully, and in their entirety, three articles were excluded as they did not satisfy the selection criteria for this review question, as their empirical data focused on presentation of approaches for specific subjects. Articles that were purely discussions with researchers were also excluded. This led to a final database of 52 studies as illustrated in Figure 1.

Figure 1. Overview of the Article Review Process



Thus, the empirical base this study is the 52 articles which were the result of this process.

Inclusion Criteria

Because there is a lack of consensus on what comprises good-quality qualitative research and what formal criteria should be used (Boaz & Sidford, 2006), it is important to account for the criteria used in any research synthesis. All of the articles included in this literature review were peer published in international scientific journals and were peer-reviewed.

Sample

The included articles of this literature review were peer-reviewed articles regarding teacher shortage from 2018-2023 in Scopus. The literature review was conducted to investigate the serious situation in the world today regarding different teacher shortages in different countries. As noted previously, some 52 articles met the inclusion criteria of this literature review. These articles represented 18 different countries such as: Australia, Belgium, England, Germany, India, Ireland, Israel, Kuwait, New Zealand, Oman, South Korea, Sweden, Switzerland, Thailand, The Netherlands, Uganda, United States (US) and Zambia. The methodologies of the studies also varied, for example, qualitative and quantitative studies.

Data Analysis

In this study, the authors independently developed a list and created a summary of the articles, and then discussed the main ideas found during the synthesis. A synthesis can differ based on what counts as data from the primary studies, and what does not (Major & Savin-Baden, 2010). This synthesis considers any data presented in the articles that are relevant to the aim of this paper. The result was the creation of a final list of articles divided into proposed coding categories, themes, and related strategies. These coding categories underwent numerous revisions, as did the themes and sub-themes, in discussion between the researchers. The themes that ran across the included articles were identified inductively and were strongly linked to the data. The steps of thematic analysis were followed to identify these themes (Braun & Clarke, 2006). Throughout the analytical process, the included articles in their entirety served as points of reference when deeper understanding was needed to define the themes. In line with Braun and Clarke (2006), the articles were read and re-read in a reflective process, first individually and thereafter discussed between the authors. The content of the included articles was thematically encoded and categorized by the described a) reasons behind, b) area/subject c) discussed solutions.

Results

In this section, the results are presented. First some descriptive statistics are presented regarding the articles reviewed. Thereafter, the results are presented in line

with the themes which emerged. The findings indicate that many of the articles analysed report on teacher attrition, teacher recruitment and teacher retention.

Descriptive Statistics of the Articles

As noted above, many countries were represented among the articles. The distribution of the countries is presented in Table 1.

Table 1. Distribution of Countries in the 52 articles reviewed

Continent	**Countries**	**Number of articles**
Africa	Zambia, Uganda	2
Asia	India, Israel, Kuwait, Oman, South Korea, Thailand	6
North America	United States (US)	33
Europe	Belgium, England, Germany Ireland, Sweden, Switzerland, the Netherlands	7
Oceanien	Australia, New Zeeland	3
International	Several countries	4

A few of articles had an international perspective. Other articles represented several countries. In total some 18 countries were represented.

As noted above, the articles were published between 2018-2023. The year and number of articles per year is illustrated in Table 2.

Table 2. Articles per year published

Year	**Number of articles**
2018	5
2019	11
2020	3
2021	6
2022	17
2023	10
In total	52

The largest number of articles was published in 2022 (17), followed by 2019 (11). The year 2020 (3) had the lowest figure of published articles.

The articles included different levels of school. The number of articles which concerned teachers in general, not a specific level, was 40 and secondary teachers a total of six. Other school levels were K-12 teachers, totalling five articles. One article was on the preschool/kindergarten teacher level.

The articles were also analysed regarding the method used in the articles. The methods in the articles reviewed are illustrated in Table 3.

Table 3. Method in the articles reviewed

Method	**Number of articles**
Quantitative	21
Position articles, literature, and policy reviews	15
Qualitative	9
Mixed methods	7
In total	52

As presented in the table above, most of the articles employed quantitative method (21). Many of the articles were position articles, literature reviews and policy reviews (15). The articles which employed Qualitative method (9) and Mixed methods (7) were more or less on the same level.

General Themes related to Teacher Shortage

Synthesizing the research, in research reviews involve identifying and combining themes and categories across the included studies in order to create a new meaning (Major & Savin-Baden, 2010) of teacher shortage. In this section, the findings regarding *reasons for teacher shortage* as well as how teacher shortage is reported as being related to *teacher shortage related to subject-specific or related to specific areas.*

Reasons for Teacher Shortage

In all the included articles of this review, the findings indicated that the reasons for the world-wide teacher shortage are *low salary* (e.g. Almutawa & Koul, 2022; Dos Santos, 2021; Sutcher, Darling-Hammond & Carver-Thomas, 2019; Wiggan, Smith, & Watson-Vandiver, 2021) *heavy workload* (e.g. Almutawa & Koul, R. 2022; Heffernan et al., 2022; Toropova, Myrberg & Johansson, 2021), *issues of health and wellbeing* (e.g. Almutawa & Koul, 2022; Dos Santos, 2021; Heffernan et al., 2022; Koh. 2022; Toropova, Myrberg & Johansson, 2021), and *low career opportunities* (e.g. Al-Busaidi & Pertanika, 2019; Almutawa & Koul, 2022; Bill et al., 2022; Carothers, Aydin & Houdyshell, 2019; Heffernan et al., 2022; Lee, Kang & Park, 2019; Wiggan, Smith, & Watson-Vandiver, 2021). The findings reported above as reasons for teacher shortage can be found in most, if not all, of the articles of this review.

Teacher Shortage related to Subject-specific or related to Specific Areas

In the included articles, teacher shortage was also seen to be related to subjects, such as different subject areas (e.g. See et al., 2022), STEM (e.g. Love & Love, 2023; Han, 2023; Peyton, van Dijk & Mason-Williams, 2023; Reinsfield & Lee, 2022). Other subject areas were seen in Special Education Needs (SEN) (e.g., Peyton, van Dijk & Mason-Williams, 2023) and Bilingual teaching, (e.g. Burke, Ceo-DiFrancesco, 2022; Hernández, Alfaro & Martell, 2022; Peyton, van Dijk &

Mason-Williams, 2023; Sada & Ward. (2022**)**. Other forms of teacher shortage reported on were related to geographical areas, such as urban or rural areas, (Pholphirul, Rukumnuaykit & Teimtad, 2023; Seeliger & Håkansson Lindqvist, 2023). Finally, teacher shortage was also seen and discussed in relation to *ethnicity*, (e.g. Goodwin, 2023; Sada & Ward, 2022). Ethnicity is an important aspect for students' identification with teachers. The same can be noted regarding the aspect of *gender***,** (e.g. See et al., 2022) of the teachers in shortage. For student learning meeting teachers of both gender on all levels of school may also be of importance.

Proposed Solutions

In the next sections, themes on the proposed solutions of teacher shortage, that run across the included articles were identified, and will be presented separately: *working conditions and job satisfaction; school policy and school administration; teacher education and side-entrances* and *important stakeholders.*

Working Conditions and Job Satisfaction

As a reason for teacher shortage teachers' working conditions and job satisfaction are frequently mentioned. The negative effects of teacher shortage are linked to teachers' job satisfaction and working conditions, both in the eyes of themselves and in the eyes of others. For strengthening teacher retention and reduce teacher attrition, the included articles proposed a change in the organizational climate and culture of schools.

Several of the articles argue that it is difficult for teachers to cope with heavy workloads and emotional stress (Heffernan et al., 2022). Therefore, there must be clear and strong investments in teacher salary, and higher status for the teaching profession (Wiggan, Smith, & Watson-Vandiver, 2021; Peytonet al., 2021) in order to gain higher job satisfaction for teachers (Toropova, Myrberg & Johansson, 2021). There is time to not only focus on limitations, but also to protect and strengthen the core work of teachers (Pendola et al., 2023). Covid19 has, though, strengthened the respect and awareness of teacher conditions (Bill et al., 2022; Dos Santos, 2021).

Another important aspect of working conditions and job relations is the focus on teacher students' career and interest (van Rooij, Fokkens-Bruinsma, & Goedhart, 2020; Al-Busaidi & Pertanika, 2019), but also gender differences (Macias & Stephens, 2019). The job satisfaction for teachers is even lower in schools with low income and/or minority pupils (Geiger, & Pivovarova, 2018). Furthermore, Almutawa & Koul (2022) claim that classroom goals and structures are the most important to teachers' job satisfaction.

School Policy and School Administration

To strengthen teacher retention and reduce teacher attrition efforts must be carried out on school policy and school administration levels. Accordingly, as reported in the articles, no teacher, nor school alone can solve the world-wide teacher shortage. Teacher shortage may be affected by government policies such as

selection system, education and training leaving age, and school funding system (See & Gorard, 2020). Administration should, therefore, develop a mutual relationship between school leaders and teachers in order to collaborate more strategically (Burke & Ceo-DiFrancesco, 2022), and support principal leadership and organizational management (Castro, 2023).

School administration and teacher education are another aspect which could support teachers. A well-defined and transparent support system for in-service teachers to retain teachers (Maruca & Zapata, 2022; O'Doherty & Harford, 2018). Policymakers should, in other words, take a distinct long-term approach to establish systematic and large-scale strategies to create a more durable and a more stable profession (Sutcher, Darling-Hammond & Carver-Thomas, 2019; Van den Borre, Spruyt, & Van Droogenbroeck, 2021).

In the literature, the shortage of bilingual teachers and teachers of colour, school administration is a challenge. Here school organizers should prepare school leaders to support teachers of color (Goodwin, 2023). They should also develop critically conscious bilingual educators (Hernández, Alfaro, & Martell, 2022). This is important in teaching pupils of different ethnicities.

When it comes to shortage in rural areas educational leaders should call for additional legislative and policy support for rural teachers (Mitchell, Hampton, & Mambwe, 2022). School organizers are suggested to be context-based; actions and activities should be based on the relative conditions of urban or rural contexts. (McHenry-Sorber & Campbell, 2019), and school administrative strategies should be used to reduce teacher shortage in high-need subjects, such as, SED in rural schools and also to critically evaluate them (Brownell, Bishop & Sindelar, 2018). In rural areas school administrators are suggested to not allow teachers to teach subjects they are not specialized to teach, and not mixed aged levels in same classes (Pholphirul, Rukumnuaykit & Teimtad, 2023). A quick fix for rurality exams is not suggested (Hollo, Floyd & Brigandi, 2019). Instead, policy makers and politicians need to initiate efforts to increase task returns and benefits (Lee, Kang & Park, 2019). Furthermore, school administration should focus on and support policies to both recruit and retain teachers (Darling-Hammond & Podolsky, 2019).

Teacher Education and Side-entrances

Teacher recruitment by teacher education is proposed to be one entry towards the downward trend of teacher shortage. Teacher education in many countries has implemented creative recruitment strategies in various areas.

One suggested solution to increase the recruitment of teachers, is to offer more placement and internship in teacher education programs. Teacher education can put positive emphasis on hands-on education in internship schools and mentors (Pauwels et al., 2022). Prior teaching and learning experiences for teacher students (Madden et al., 2022) has shown to be effective, since early teaching experiences are positive to attract students to teacher programs and higher their perception of teaching as a career – especially culturally and ethnically diverse students (Carothers, Aydin & Houdyshell, 2019). 'Grow Your Own' (GYO) in school district plans for increase participants in teacher programs (Hamman, Matteson &

Nguyen, 2023). Support apprenticeship by GYO, in teaching to recruit and prepare teacher of colour and bilingual educators (Heller, 2021).

The mitigation of the teacher shortage within specific subjects is discussed based on different aspects. Recruitment and retention of bilingual teachers is needed (Sada & Ward, 2022). Further, increased opportunities in teacher programs for bilingual teachers are called for (Jimenez-Silva, Ruiz & Smith, 2022) and should therefore be taken into account. Regarding SEN teachers, teacher education must prepare teacher students for behavioral problems to avoid teacher attrition (Koh, 2022). There are though different perceptions between teachers and school administrator about the needs and roles of SEN teachers (Hagaman & Casey, 2018). Recruitment strategies of SEN teachers and teacher preparation programs are needed (Chamberlin-Kim, Tarnay & Wells, 2019). Teacher education programs should invest more for SEN-teachers in high shortage areas (Peyton et al., 2021), with the purpose to increase recruitment of teachers working with sensory impairments and other SEN in rural and remote schools – and to keep them there (Davis, Pogrund & Griffin-Shirley, 2020).

Another issue for teacher education to elaborate is imbalance between geographical areas within a country. Undergraduate education within areas that have high-needs should be expanded (Peyton, van Dijk, & Mason-Williams, 2023). The importance of mobility of teacher education between states could alleviate teacher shortage in rural areas (Seeliger & Håkansson Lindqvist, 2023). One aspect is that rural areas may be located a long distance from teacher educational programs and therefore cause shortage of teachers in rural areas (Goldhaber et al., 2020).

To recruit students to teacher education programs teacher education programs must be more sought for and more attractive. Teacher education must adapt learning programs to the students' learning and interests (Van den Borre, Spruyt, & Van Droogenbroeck, 2021; Reinsfield & Lee, 2022). Interest and hands-on hobbies related STEM education as recruiting factor to teacher programs (Love & Love, 2023). The importance of tailor-made teacher programs to attract unemployed academics to teaching (Ramot & Donitsa-Schmidt, 2021). Also, adressing individuals who would focus on building effective relationships with pupils in urban, high need schools (Wronowski, 2018). One short-term solution for teacher shortage, is to certify teachers to teach other subjects through an exam process. However, teacher validation through an exam process is not advised (Hollo, Floyd & Brigandi, 2019). Non-specialist teachers are being used from other learning areas than they are educated in (Reinsfield & Lee, 2022). Even the system of contract teachers may solve teacher shortage in short terms, but that have major impact on teachers working conditions. This quick fix, often due to budget, will lead to demoralization and disempowerment of educated teachers (Apat & Swain, 2023).

Important Stakeholders

Other themes that emerged among the proposed solution for teacher shortage in the reviewed articles were also seen as important. Here important stakeholders were reported: *Teacher unions* and *supportive parents.*

Teacher Unions

Teacher unions are important stakeholders for teachers in their profession. To retain teachers of both genders, teacher unions should address female teachers in the same manner as they address male teacher in various matters and issues. There is a difference in the way teacher unions focus mostly on male teachers, which has impact on the retention of teacher of both genders (Han, 2023).

Supportive Parents

Supportive parents are also important stakeholders. When it comes to recruitment at an early stage, pupils are more likely to consider teaching as a future profession when parents, family members, community and others encourage them to become teachers. This is especially true if pupils believe that expectations are reasonable (Christensen et al., 2019). Parents' support and encouragement of their children to become teachers is also depending on the encouragement of people outside the family (Christensen et al., 2022; Davis, Pogrund & Griffin-Shirley, 2020). As parents and teachers in rural areas influence each other, positive interaction between teachers and parents could increase the retention and engagement (Arinaitwe & Corbett, 2022).

Results in Summary

In summary, the reason for world-wide teacher shortage are low salary heavy workload issues of health and wellbeing and low career opportunities. subject-specific or related to specific areas. Possible solutions were seen to be improving working conditions and job satisfaction; school policy and school administration which supports teachers; attractive teacher education and possible side-entrances and the support of important stakeholders.

Discussion

The aim of this paper was to study teacher shortage through conducting a literature review in order to analyse peer-reviewed articles regarding teacher shortage from the period of 2018-2023. The following questions were posed: 1) How are the causes of the teacher shortage described in current literature? and 2) How do the reasons that have emerged for teacher shortage give an understanding of teacher attrition, teacher recruitment and teacher retention? In answering the first research question, many themes emerged which present challenges which lie behind the current status of teacher shortage.

In regard to teacher attrition, issues regarding low salary, heavy workload, health and well-being and low career opportunities, as reported in this study, are well in line with previous policy (European commission, 2015; Eurydice, 2018) and research Federičová, 2020; Håkansson Lindqvist, Boström & Gidlund, 2022;

O'Doherty & Harford, 2018). These aspects are reported in regard to the relatively low pay of teachers (Dee & Goldhaber 2017; Aldeman, 2015; Ingersoll 2011; Hutchings 2011; Dolton, Tremayne, & Chung 2003). Other aspects such as low status, poor career opportunities and heavy workloads for teachers in schools are also reported (Borman & Dowling 2017; Hayes 2017; Hobson, Giannakaki, & Chambers 2009). International trends point toward an increase in teacher shortage as the number of children entering the educational system increases, teachers retire and leave the profession (UNESCO, 2024). Policies to alleviate teacher attrition will be necessary to promote teacher recruitment and provide a favourable picture of the teaching profession.

In regard to teacher recruitment, entries in teacher education are proposed to be one step towards the downward trend of teacher shortage. Teacher education programmes in many countries have implemented creative recruitment strategies in various areas. Many of these strategies may be both durable and effective. Strategic initiatives will be important to mitigate the challenges related to gender (Aldeman, 2015; Dee & Goldhaber, 2017), ethnic aspects (NCES, 2020) and geographical aspects (Darling-Hammond, 2010; Adamson & Darling-Hammond, 2012). How different countries put policies in place to support recruitment in these groups will demand well thought-through initiatives. New paths in teacher education for male teachers and teachers of ethnic minorities as well as special initiatives to support STEM, SED and bilingual education may also have impact on turning the trend of teacher shortage. Here, policies must also have effective impact in practice.

In regard to teacher retention, in-service teacher will need to support to continue in the teaching profession. New teacher students and new teachers, who enter the teaching profession though new pathways, will need the support of experienced, in-service teachers. This support will be provided by in-service teachers already in the educational system and will require time and effort. Thus, the retention of in-service teachers will be key to support new teachers in their first years of work. The attractiveness of teacher education, and the teacher profession in general will also be important. For new teacher students, both younger teacher students and more experienced academics in other professions who choose a new path in life in teaching, will also be important groups for successful recruitment but also to retain these teachers over time. As also seen in this study, school leaders, school organizers, teacher unions and supportive parents will also be important. These efforts together will most likely provide effective support for teacher retention.

In summary, the results of this study show that teacher shortage is a challenge in many countries throughout the word. Further, the results of this study could be interpreted as a call for action in each specific country context and the acknowledgement of different educational contexts. The reasons for teacher shortage are well reported in the literature. Therefore, it will be important to find new ways to collaborate internationally to disseminate new research on possible solutions to teacher shortage and to identify effective and sustainable efforts and initiatives through policy. If pupils are to receive quality education, in line with the policy goals set by UNESCO (2024), further collaboration regarding how to take on

the challenges of teacher attrition, and at the same time promote and support teacher recruitment and retention will be necessary in order to alleviate teacher shortage.

Conclusions

In conclusion, teacher shortage according to the literature is multifaceted, complex and context-based. Moreover, all of the reasons for teacher shortage and the possible solutions appear to interact. Implications for practice involve how different stakeholders can support teachers as professionals. This may involve efforts in policy to increase salaries, prioritising teachers core work with teaching and learning through a shift from administrative work to planning activities for pupils' learning. Efforts to support teachers' status. Supporting new students to enter the teaching profession will also be of importance. Teachers are employed by schools, and schools are submitted to local and national levels to carry out their teaching mission. Flexible and strengthened organizational management on local and national level may support these efforts. With this in mind, the results of this study included proposed changes of school policy and school administration levels on different levels. Initiatives in which governments, school organisers, school leaders, teacher unions, supportive parents and society together take on the challenges of teacher shortage will be necessary. These joint initiatives will most likely alleviate teacher shortage and ease the impact of teacher shortage on the quality of education for pupils in schools.

Limitations and Future Research

In this literature review, the main limitations are found in the search of only one database. One the one hand, this could mean that articles which have met the search criteria were not identified in this study. On the other hand, the Scopus database was chosen for the high level of quality in this database. In the light of these limitations, the sample of articles has provided an updated picture of the challenges in teacher shortage as well as solutions. Future research could a wider and more in-depth literature involving several databases to acquire a deeper understanding of teacher shortage.

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Lifelong Learning for Work Life: A Perspective from Norway

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The Centre for Lifelong Learning (SELL) at Inland Norway University of Applied Sciences (INN) has been crafting tailored, flexible educational programs for working adults for thirty years, seamlessly integrating education with professional life. This paper underscores SELL's pivotal role in furnishing pertinent formal and informal education for individuals and businesses in the workforce, aligning with governmental strategies for lifelong learning. Our study poses two research questions: RQ1. What are SELL's current key functions and activities? RQ2. How can SELL bolster political agendas and address future workforce learning needs? Through document analysis spanning Norwegian authorities, INN, and SELL, we found concordance between governmental lifelong learning policies, INN's strategy, and SELL's focus areas. However, there's a gap in follow-up and prioritization. Recommendations include establishing dedicated units for external activities at educational institutions and fostering closer collaboration between academia and industry to enhance the relevance of offered competencies. Direct engagement between educational institutions and learners is crucial, possibly facilitated by streamlined access. Strengthening this cooperation is imperative for advancing workforce competence in tune with market demands.

Keywords: Education, lifelong learning, work life, document analysis

Introduction

In the foreseeable future, we anticipate confronting intricate societal challenges that will precipitate substantial transformations in the workforce. The evolving landscape of work necessitates both an increase in skills and adaptability, placing heightened demands on the education sector (Ministry of Education and Research, 2023). The burgeoning demand for specific skill sets underscores the significance of continuous skill development within the workforce, essential for fostering competitiveness and driving societal value creation. Effective collaboration among employers, employees, and government entities is pivotal for successful skills development initiatives, with the education sector poised to play a pivotal role in addressing future skills requirements (Ministry of Education and Research, 2022).

Lifelong learning is defined as "all organized and unorganized learning throughout life, and includes formal education as well as informal learning through work and other activities" (author´s translation) (Kunnskapsdepartementet, 1998). In our study, we have defined lifelong learning as encompassing structured educational

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opportunities within higher education tailored for working adults throughout their professional careers.

According to the CPD Service, "Continuing Professional Development is a commitment to ongoing lifelong learning. CPD[1] encourages looking forward and identifying opportunities to learn something new, refresh existing knowledge, improve skills, or simply keep up-to-date with the latest developments within a particular profession or industry. In practice, CPD can mean everything from taking a training course or attending an educational event, to studying for new qualifications or learning new aspects of a job" (The CPD Certification Service, 2024).

The education sector has an important role in developing subjects and subject areas that are relevant to working life and that enable employees to perform the tasks required in today's society (Ministry of Education and Research, 2023). The topic is important to put on the agenda because lifelong learning has become an important concept in the Norwegian education system. This has been clearly stated in paragraph 1-3.d in the University and University College Act from 2005 (Kunnskapsdepartementet, 2005). Here it is a fact that higher education institutions in Norway must "contribute to lifelong learning and offer continuing education" (author´s translation) (Kunnskapsdepartementet, 2005). Furthermore, future cooperation between educational institutions and working life must be strengthened to develop relevant offers (Kunnskapsdepartementet, 2019). It is also important to look at the challenges and needs adults experience, so that learning new knowledge can be adapted to the individual's work situation (Tømte et al., 2015). Most Norwegian universities currently offer flexible educational opportunities that support lifelong learning through distance learning, part-time studies and continuing education.

At the Inland Norway University of Applied Sciences (INN), the center for lifelong learning (SELL in Norwegian), established in 1990, has played a development role and been a key provider of continuing education for the college (Lesjø, 2000).

SELL[2] boasts interdisciplinary proficiency in crafting and executing customized, adaptable, and pedagogically tailored competency programs for working adults, seamlessly integrating education and professional practice. Their expertise spans the initiation and procurement of projects, proficient project management, and comprehensive needs assessment within corporate settings. Moreover, they excel in tailoring study models to suit diverse organizational contexts, devising learning designs, pedagogical and technological facilitation, and conducting evaluation and research on competency programs, constituting the cornerstone of their operations (SELL, 2024e, 2024a).

[1]In this article, we have chosen to use the term Continuing Professional Development (CPD) as a collective term for Further- and Continuing Education, which we use in a Norwegian context. CPD is about continuing professional development through learning something new, updating existing knowledge and improving skills within a profession or industry.

[2]SELL is organized with a broad and interdisciplinary project portfolio at Inland School of Business and Social Sciences - Faculty of Economics and Social Sciences (SELL HHS), and in a separate unit for competence development in the school and kindergarten sector at the Faculty of Teacher Education and Pedagogy (SELL department LUP) (SELL, 2024d).

Research Questions

Utilizing SELL as our focal point, we aim to delve into the requisites for higher education institutions and analogous units like SELL to assume a more proactive role in nurturing and fostering knowledge enrichment within professional domains, aligning with governmental agendas for lifelong learning. Consequently, our study examines two primary research questions (RQs):

RQ1. What are SELL's current key functions and activities?
RQ2. How can SELL bolster political agendas and address future workforce learning needs?

To tackle these two RQs, we scrutinized pertinent documents illuminating aspects crucial for SELL's advancement and potentially holding transferable relevance for other educational establishments.

Paper Outline

The paper offers an overview of essential documents pertinent to addressing the two research questions. Initially, we conduct a literature review followed by a methodological outline. Subsequently, we present the outcomes of the document analysis, aligning them with the two research questions. Lastly, we summarize our principal findings, draw conclusions, and critically assess the study's limitations while proposing potential avenues for future research.

Literature Review

To organize our literature review effectively, we've classified the documents into three tiers:

1. Documents at the Norwegian authority level, encompassing overarching political policy documents.
2. Documents at the institution level, featuring guidelines derived from governmental directives.
3. Documents at the unit level, providing guidance from within the institutional framework.

Below, we present these documents in hierarchical order, beginning with those from the Norwegian authority level.

Documents at the Norwegian Authority Level - Overarching Political Policy Documents

Act Relating to Universities and University Colleges and Preparatory Work for the Act

The Universities and University Colleges Act (Kunnskapsdepartementet, 2005) regulates the purpose, scope and tasks of all universities and university colleges in Norway[3]. The purpose of the Act is to offer and facilitate teaching, research and dissemination at educational institutions, and the Act stipulates that universities and university colleges "shall contribute to lifelong learning and offer continuing and further education" (author´s translation). This is a statutory task, on a par with the six other core tasks listed in section 1-3 (Kunnskapsdepartementet, 2005).

It's noteworthy that in the preliminary stages of drafting the Act, there are explicit acknowledgments of educational institutions' social responsibility, encompassing lifelong learning and continuous education. The Act is designed to afford institutions the flexibility needed to ensure that students' educational demands for labor market qualifications are adequately addressed (Kunnskapsdepartementet, 2023b).

White Papers and a Report to the Norwegian Parliament

White papers are drafted by the Norwegian Government to address issues to the Norwegian Parliament that do not necessitate immediate decisions (Norwegian Government, 2012). These papers serve the overarching aim of coordinating research and education policies across sectors, aiming to foster a consistent, long-term, and foreseeable policy framework with clearly defined objectives and priorities (Norwegian Government, 2012). In our literature review, we have identified two white papers that were deemed most pertinent for our research objectives.

White Paper No 5 to the Norwegian Parliament (2022-2023) Long-term plan for research and higher education 2023–2032

The purpose of the white paper no 5 titled: *Long-term plan for research and higher education 2023-2032* to the Norwegian Parliament is to present the Norwegian government's long-term policy for research and higher education with the aim of strengthening competitiveness and innovation, environmental, social and economic sustainability, as well as high quality and accessibility in research and higher education. Priority is given to the following themes: ocean and coast, health, climate, environment and energy, enabling and industrial technologies, societal security and preparedness, and trust and community (Ministry of Education and Research, 2022).

There exists a substantial demand for job requirements, underscoring the significance of developing and applying new skills within the professional sphere for enhancing competitiveness and societal value creation. Effective collaboration among employers, employees, and government entities is imperative for the successful development of skills. Moreover, the education sector is poised to play a crucial role in addressing future skills requirements and facilitating skill acquisition (Ministry of Education and Research, 2022).

[3]A new law comes into force on August 1, 2024, but there are no significant differences within the topics covered by this study.

The Norwegian government has identified three overarching goals for research and higher education in the period 2023-32: 1. Strengthened competitiveness and innovation capacity; 2. Environmental, social and economic sustainability; and 3. High quality and accessibility in research and higher education (Ministry of Education and Research, 2022).

White Paper No 14 to the *Norwegian Parliament* (2022–2023) Outlook on the skills needs in Norway

The objective of White Paper No. 14, titled "Outlook on the skills needs in Norway," is to delineate the skills requirements within the workforce, strategies to increase workforce participation, and the alignment of the education system with societal needs. It also emphasizes the importance of providing accessible and adaptable education options for a broader segment of the population and promoting lifelong workplace learning. Development agreements, focusing on lifelong learning, flexible, and decentralized education, have been established between educational institutions and the Ministry of Education and Research. Additionally, there is a concerted effort to enhance collaboration between educational institutions and the workforce, as well as local and regional authorities, to address skills gaps and optimize the organization of basic and advanced education (Ministry of Education and Research, 2023).

Official Norwegian Report 2019:2 Future Competence Needs II – Challenges for Competence Policy

Official Norwegian Reports serve as inquiry documents that frequently serve as the foundation for reports to the Norwegian Parliament. Their purpose is to explore a knowledge base and propose potential strategies for addressing societal challenges (Norwegian Government, 2007).

The Official Norwegian Report 2019:2, entitled "Future Competence Needs II – Challenges for Competence Policy," was authored by a committee tasked by the Norwegian government, known as Kompetansebehovutvalget in Norwegian. Its purpose is to identify challenges and dilemmas related to future skills requirements, providing a foundation for strategic competence planning and decisions by both governmental bodies and the workforce. The report emphasizes the necessity for enhanced collaboration between higher education institutions and the workforce, aiming to ensure that such interaction results in the development of more pertinent study programs (Kunnskapsdepartementet, 2019).

Documents at the Institution Level - with Guidelines from the Government Level

The 2024 Letter of Allocation to INN from the Ministry of Education and Research

Annually, universities and university colleges in Norway receive a letter of allocation from the Ministry of Education and Research, delineating financial allocations and institutional priorities based on political directives and the national

budget. This communication serves to guide institutional management by providing signals for forthcoming priorities. The letter encompasses the financial framework, sector priorities, and goals for the upcoming period. Additionally, the development agreement, comprising tailored objectives and management parameters agreed upon between the Ministry and each institution, is now integrated within the allocation letter. The 2024 Letter of Allocation to INN offers a comprehensive overview of the government's expectations for all Norwegian universities and university colleges: "Universities and university colleges shall prioritize lifelong learning and flexible and decentralized offerings so that education and skills development are accessible and independent of place of residence and life situation" (author´s translation) (Kunnskapsdepartementet, 2023a).

Objectives have been delineated for the higher education sector and INN's strategic priorities to aid in accomplishing the national sector objectives outlined in the long-term plan. Development agreements are crafted collaboratively between the Ministry of Education and Research and Norwegian universities and colleges. For 2024, the following overarching and enduring sector objectives are applicable:

1. High quality in education and research
2. Sustainable social development, welfare and innovation
3. Good access to education, research and expertise throughout the country

A section in 2024 Letter of Allocation to INN is referred to as a development agreement with INN for 2023-2026 (Kunnskapsdepartementet, 2023a). Here four objectives are stated, in which two objectives were considered to be of relevance for our study.

Objective 3 delineates INN's commitment to spearheading lifelong learning initiatives. Specifically, it entails clarifying targeted measures and assessing which educational programs can offer flexible solutions. Additionally, INN will establish administrative systems for monitoring and ensuring quality, a process conducted in collaboration with stakeholders from society and the workforce, focusing on course and sub-course levels (microcredentials) (Kunnskapsdepartementet, 2023a).

Objective 4 underscores INN's role as a regional influencer in Inland Norway and a national contributor through the further development of platforms and networks for engagement. INN's regional presence fosters collaboration opportunities, with a management parameter aimed at enhancing connections with society and the workforce by expanding regional and national networks and partnerships (Kunnskapsdepartementet, 2023a).

INN

INN is a medium-sized university college in eastern Norway, established in 2017 following a merger between two university colleges. INN is an important competence institution in the region and collaborates extensively nationally and internationally, both in research and education. INN has a wide range of subject areas that are relevant to working life and society, and will respond to the need for research and continuing education in working life and society, regionally and

nationally, and will be a driving force in social development in the region and make its mark nationally and internationally (INN, 2024a).

The academic activities are organized into six faculties led by a dean with academic and administrative responsibility for their area. A board decision (36/17) gives the faculties academic and strategic responsibility for externally funded activities and academic and strategic responsibility for their subject areas (HINN, 2017). Continuing education, lifelong learning and collaboration with working life with external funding are the responsibility of the faculties themselves to further develop. In 2020, the university college board decided that the SELL, which until then was organized at the institutional level under the Pro-rector for Public Affairs, should be transferred and organized at one of the university college's faculties (HINN, 2020).

INN's activities related to continuing education, lifelong learning and collaboration with working life at the university college include positions at several levels. The Education Department has strategic responsibility for, among other things, educational quality, educational development work, further development of INN's overall study portfolio, including lifelong learning and continuing education (INN, 2024b).

INN´s Strategy 2021-2026

INN's strategy for the period of 2021-2026 distinctly acknowledges the imperative for adapting to the evolving dynamics of the workforce, particularly in a region characterized by a significant elderly population, low formal education rates, and dispersed settlement patterns. Prioritizing accessibility to education across all stages of life, INN aims to achieve this through flexible and centralized study programs developed in close partnership with regional, national, and international collaborators. Positioned as a frontrunner in national lifelong learning initiatives, INN boasts an extensive array of continuing and advanced education offerings developed in tandem with industry partners. Bolstering this study portfolio further stands as a pivotal strategy moving forward (INN, 2021).

Documents at the Unit Level - with Guidance from the Institutional Level

SELL at INN

SELL was established in 1990 at INN, formerly known as Oppland District University College, with the primary objective of managing the college's distance learning initiative. These programs were designed to cater to adults in the workforce seeking skills development opportunities, locally, regionally, and nationally, leveraging new technologies for educational dissemination (Lesjø, 2000).

As of 2021, SELL has been integrated into the Inland Norway School of Business - Faculty of Economics and Social Sciences (HHS), operating directly under the dean's purview, overseeing the faculty's externally funded educational and research activities. While similar tasks at other faculties within INN are organized differently, SELL maintains its distinctive scope and range of activities (INN,

2024b). Currently, SELL boasts approximately 25 employees, serving over 2,000 students and 3,000-5,000 course participants annually, constituting a portion of the university college's total enrollment of around 14,000 individuals. Its operations are sustained through external funding from donors, businesses, and individual students/ course participants (SELL, 2024b).

A hallmark of SELL's approach has been its provision of flexible study models incorporating synchronous and/or asynchronous teaching and learning methods. Central to its educational practices has been the integration of film in teaching, alongside the exploration of novel pedagogical and technological solutions to develop and deliver competency programs for employees of major national organizations, such as the Norwegian Labour and Welfare Administration, the Norwegian Armed Forces, and the municipal sector (SELL, 2024b). Over the years, SELL's evolution has seen a transition from the distribution of educational films via satellite and Video Home System (VHS) in the 1990s to the transmission of a significant number of online study programs via the Internet, often complemented by physical or digital meetings (SELL, 2024b).

SELL's primary mandate, in collaboration with the academic environments at HINN, is to devise flexible, relevant, and practice-oriented competency initiatives for companies and individuals in society and the workforce. This is achieved through the application of learning-promoting methodologies in research-based and well-founded pedagogical approaches. SELL's expertise encompasses various domains, including project management encompassing administration and finance, pedagogy/didactics for adult learners and diverse groups, project acquisition, study administration, adult learner facilitation, collaboration and networking, as well as proficiency in educational material production, learning technology, and market knowledge (SELL, 2024b).

SELL's Action Plan

Since its establishment, SELL has developed action plans for the business. The purpose has been to choose a long-term direction for what to work on and how to position itself in the market. The action plan also follows up on strategic plans at INN and at the faculty.

SELL's action plan aims "to fulfill INNs' strategy of being a preferred player in lifelong learning by 1) being a driving force in development work and a provider of continuing education in collaboration with the academic environments, 2) being a contact point for working life and 3) being updated on political guidelines and instruments for lifelong learning" (author´s translation) (SELL, 2024c).

The main goal of the action plan is to develop and offer "flexible, relevant and practice-oriented competence offers for society and working life"(author´s translation) (SELL, 2024c). This will be done in collaboration with the academic environments at the faculty by:

- Strengthen the scope of relevant educational offerings regionally and nationally

- Increase the quality of study programs by focusing on active teaching and learning methods to increase learning outcomes
- Increase access to education for more people through flexible off-campus offerings that enable adults to combine education with work, family and other activities, and
- An appropriate organization of SELL for interdisciplinary collaboration with academic environments at INN and with external partners.

The target group for the competence offerings is companies in working life and individuals who need skills development. In addition, SELL's target group is also defined as the individual academic environments at the university college and external partners in the higher education sector (SELL, 2024c).

Methodology

Document analysis serves as a valuable method for qualitative case studies (Stake, 1995; Yin, 1994), making it a suitable approach for examining SELL's activities and pertinent political documents central to both SELL and the research questions at hand. Additionally, the study encompasses other pertinent documents, including SELL's and INN's strategies on lifelong learning. Consequently, the study relies on documents deemed crucial for yielding insights into the investigation's objectives (Grønmo, 2015).

Document Analysis as a Method

Document analysis is a systematic procedure for reviewing or evaluating documents, both printed and electronic material (Bowen, 2009). Similar to other analytical methods in qualitative research, document analysis requires that data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Corbin & Strauss, 2008; Rapley, 2007).

In our study, we aim to investigate how SELL can augment its engagement in promoting knowledge advancement within the workforce, while aligning with governmental objectives for lifelong learning. To accomplish this, we will focus on two research questions (RQs):

RQ 1: What are the most important functions and core activities of SELL today?
RQ 2: How can SELL contribute to fulfill political strategies and support the need for lifelong learning in the working life of the future?

The authors first independently identified and then discussed key themes, concepts, and keywords crucial for the aim of our study and that was relevant in order to answer our two RQs. The interrater reliability (IRR) (Fink, 2010) among the authors was very high, indicating a strong agreement on the chosen keywords, concepts and descriptions of key themes. The authors ended up with the following keywords, concepts and descriptions of key themes: lifelong learning, CPD, skills

needs, and collaboration with the workforce. To address our two RQs, we then analyzed both official and internal documents selecting only those documents that adhered to these chosen keywords, concepts and descriptions of key themes and with a content that indicated lifelong learning, CPD, skills needs, and collaboration with the workforce.

Procedure

Data collection involved identifying and scrutinizing official and internal documents deemed pertinent to address the two research questions. The analysis proceeded through three stages:

1) Initial documentation review: We sourced and selected relevant political documents, internal materials, website content, and notes from both INN and SELL to establish an overview of available documents.
2) Content organization: We systematically extracted relevant information from the selected documents, generating summaries to facilitate comprehension. Subsequently, we categorized and sorted the documents based on criteria pertinent to the research questions.
3) Interpretation: We interpreted the content in relation to the two research questions and the identified criteria, facilitating a deeper understanding of the data and its implications for the study.

Documents used in the Analysis

We also took into account several factors such as the purpose, age, credibility, and representativeness of the documents during the selection process. These documents originate from institutional sources, and our interpretation was guided by our understanding of their intended purpose. Table 1 provides an overview of the analyzed documents, with the superscript number [1] or [2] indicating their relevance to either RQ 1 or RQ 2.

Table 1. *Documents Analysed and Their Relevance to the Two Research Questions* *Documents at the Norwegian authority level - overarching political policy documents*

The Universities and University Colleges Act (Kunnskapsdepartementet, 2005)[2]
The White Paper 5 titled: *Long-term plan for research and higher education 2023-2032* (Ministry of Education and Research, 2022) [2]
The White Paper 14 titled: *Outlook on the skills needs in Norway* (Ministry of Education and Research, 2023) [2]
The Official Norwegian Report 2019:2, entitled "Future Competence Needs II – Challenges for Competence Policy (Kunnskapsdepartementet, 2019) [2]
Documents at the institution level - with guidelines from the government level
The 2024 Letter of Allocation to INN (Kunnskapsdepartementet, 2023a)[1,2]
INN's strategy 2021-2026 (INN, 2021) [1,2]
Documents at the unit level - with guidance from the institutional level
Action plan (SELL, 2024c) [1,2]
Organization (SELL, 2024b) [1,2]
Center for Lifelong Learning (SELL, 2024d) [1,2]
SELL´s development of educational offers (SELL, 2024e) [1,2]
SELL´s view on flexible learning for adults(SELL, 2024a) [1,2]

[1]RQ1: What are SELL's current key functions and activities?
[2]RQ2: How can SELL bolster political agendas and address future workforce learning needs?

The document selection criteria primarily revolved around key themes such as lifelong learning, CPD, skills needs, and collaboration with the workforce.

Other forms of evidence, such as cultural artifacts, were not included in our analysis as they were deemed outside the scope of our investigation.

Results and Discussion

The findings are categorized under five main headings, each containing discussions of relevant documents. Through our analysis, we have identified several factors that collectively address our two research questions. Following the discussion of results, we will offer a summary to address our research inquiries. The five main headings are outlined in the subsequent section of the paper in the following sequence:

1) Political guidelines on lifelong learning are consistent with the institutions' strategy and focus areas
2) Political guidelines and the INN's commitment to lifelong learning harmonize with SELL's focus areas and expertise
3) Competence development is best achieved through direct contact with students and working and social life
4) Externally funded activities are organized in separate units
5) Interaction between higher education and working life

Political Guidelines on Lifelong Learning are Consistent with the Institutions' Strategy and Focus Areas

The Universities and University Colleges Act is the most important political instrument, and gives clear guidance and responsibility to the institutions to take responsibility for lifelong learning and continuing education (Kunnskapsdepartementet, 2005).

The White Paper 5, titled: *Long-term plan for research and higher education 2023-2032*, also states that lifelong learning and flexible and decentralized offerings are a key part of the institutions' social mission (Ministry of Education and Research, 2022). This mission and responsibility is also consistently reflected in the authorities' allocation letter from the Ministry of Education and Research to INN (Kunnskapsdepartementet, 2023a), as well as INNs' strategic plan (INN, 2021) and other information about INN via its website (INN, 2024c), as well as SELL's action plan (SELL, 2024c) and other information about SELL via its website (SELL, 2024d).

The 2024 Letter of Allocation states that INN will be a driving force for lifelong learning, a regional force in the inland region in Norway and a national contributor by further developing arenas and networks for collaboration. Management parameters specify that studies/courses of various sizes are to be developed, as well as administrative systems for follow-up and quality assurance (Kunnskapsdepartementet, 2023a).

INN's strategic plan addresses the desire to be a driving force for the need for lifelong learning in the working life of the future and thus responds to political strategies (INN, 2021). INN's strategy appears to be forward-looking, clear and up-to-date on today's challenges. Nevertheless, it may appear that there are major tasks to be solved with regard to today's challenges in the sector, where there are complex societal challenges to be solved through education and research.

In the long-term plans for the faculties at INN, all are concerned with interaction with working life and society, but the focus on lifelong learning and lifelong learning, continuing professional development (CPD) varies (SELL, 2024a). Tømte et al. (2015) point out that strategies for CPD, known as EVU in Norway are generally not widespread, even at institutions with their own EVU departments, and that CPD has been overshadowed by other initiatives (Tømte et al., 2015).

The Norwegian directorate Kompetanse Norge[4] states that CPD initiatives must be more clearly stated in the educational institutions' strategic plans and mandates, and that the institutions themselves must clarify the role of CPD. This could help to ensure that CPD becomes an integrated and stable part of the study portfolio and is better anchored at department and faculty level, but there is a need

[4]Kompetanse Norge was a directorate under the Ministry of Education and Research with the task of contributing to increased participation in working life and society. On July 1, 2021, it was merged with several other agencies to form the Norwegian Agency for Higher Education and Skills (Huseby, 2023).

for stronger national guidelines and incentives for the sector to prioritize this (Kompetanse Norge, 2018b).

According to the strategic plan for INN, it appears that INN is an institution that has clear strategies for its focus on lifelong learning and collaboration with working life and society, which are also embodied in the faculties' strategies and measures through the long-term plan (INN, 2021).

The 2024 Letter of Allocation from the Ministry of Education and Research supports this by stating that INN's work on CPD, lifelong learning and flexible and decentralized offerings is well described in strategies and development plans, but it is pointed out, however, that it is not prioritized or followed up well by the faculties' action plans and the number of CPD offerings (Kunnskapsdepartementet, 2023a).

We observe a consistent dedication to lifelong learning spanning from the highest political directives outlined in the Universities and University Colleges Act (Kunnskapsdepartementet, 2005), through the government's allocation letter and white paper, down to the unit level within the educational institution's strategic documents.

Consequently, there seems to be alignment between the authorities' directives and INN's strategies and development agendas in this domain. However, a gap may exist concerning action plans, prioritization, and follow-up within INN's framework.

Political Guidelines and the INN's Commitment to Lifelong Learning Harmonize with SELL's Focus Areas and Expertise

The White Paper 5 titled: *Long-term plan for research and higher education 2023-2032* points out that access to flexible education programs that can be taken as continuing education and in combination with a job should be strengthened, and is concerned that in order to increase the accessibility of study programs, digital teaching methods must be used to adapt the study programs to regional and more local skills needs (Ministry of Education and Research, 2022).

Furthermore, white paper no 14 titled: *Outlook on the skills needs in Norway* provides direction for higher education institutions' priorities to increase the number of flexible study programs for more people, through lifelong learning (Ministry of Education and Research, 2023). As we have also seen, this is reflected in the Universities and University Colleges Act through the educational institutions' tasks related to lifelong learning (Kunnskapsdepartementet, 2005).

The 2024 Letter of Allocation to INN provides guidelines on following up and developing relevant continuing and further education offerings throughout Norway, and INN is expected to follow up on allocated resources to develop flexible and decentralized education (Kunnskapsdepartementet, 2023a).

The INN's strategy and the authorities' guidelines emphasize a focus on lifelong learning, continuing education and collaboration with working life (INN, 2021). All of this harmonizes with the objectives and focus areas SELL has emphasized, and the expertise developed at SELL, cf. the action plan and information about SELL (SELL, 2024c, 2024b).

The Norwegian directorate Kompetanse Norge refers to the sector's lack of expertise and an administrative apparatus for investigating the companies' skills needs and organizing and adapting the skills measures accordingly. It is also pointed out that the sector has few people with sufficient networks, experience and expertise to develop business-related CPD offerings (Kompetanse Norge, 2018a). This also supports the need for an organization similar to SELL, which has a large network in working and social life as well as pedagogical expertise and tools to develop relevant and tailored competence offerings for working life (SELL, 2024e, 2024a).

The Continuing Education Committee's report from the Norwegian Directorate Kompetanse Norge on the knowledge base states that CPD units at educational institutions in Norway have a high degree of pure administration. It points out a lack of broader expertise to solve more complex tasks in the development of competence programs. And through this, offer holistic deliveries in competence programs regardless of size. This is highlighted as an essential competence to succeed with customized CPD offers for working life (Kompetanse Norge, 2018b).

This indicates that SELL has expertise that is adapted to what the Continuing Education Committee (Kompetanse Norge, 2018b) has pointed out as a lack of expertise at educational institutions. In addition to administration, SELL has comprehensive expertise in delivering competence programs (SELL, 2024b).

At SELL, the development work is carried out in close collaboration with the professionals who deliver the academic content (SELL, 2024b). The competence described at SELL is in line with Mishra and Koehler's (2006) knowledge framework, the TPACK model, which outlines three pillars; technology, pedagogy and academic content highlighted as key academic components for developing education with digital tools. However, scrutinizing the TPACK model, it appears that SELL has an additional fourth pillar that deals with knowledge about and facilitation for the adult student, which is required in connection with combining studies with a work situation. This shows that SELL focuses on how interaction with working life and the target group of working adults is a recurring theme in the development and operation of study programs.

An internal study at INN that mapped external collaboration found that working life finds it difficult to know where to contact in order to establish collaboration with the university college. It has been suggested that having both an institutional level and a faculty level where public relations and work with CPD are organized very differently is confusing for working and social life (Stokke et al., 2020).

It may thus appear that SELL and similar units have a competence composition and structure that could serve as a "doorway" to an educational institution and be a link between academic environments and working life within lifelong learning and CPD.

Competence Development is best achieved through Direct Contact with Students and Working and Social Life

To ensure high quality and accessibility in research and higher education, the white paper titled: *Long-term plan for research and higher education 2023-2032* states that a decentralized structure will be used to contribute to lifelong learning. It is also pointed out that a closer link between the education offered and local businesses will strengthen the relevance of education. In summary, the white paper points to the importance of proximity to working life through accessibility and decentralized location. In addition, access to flexible study programs such as continuing education will be strengthened (Ministry of Education and Research, 2022).

In the 2024 Letter of Allocation given to INN, the Norwegian Government states that competence needs are best solved by giving employees in the first line at educational institutions increased confidence. We interpret the first line as those individuals who has the closest contact with students and working and social life (Kunnskapsdepartementet, 2023a).

The authorities also state in the 2024 Letter of Allocation to INN that it is in direct contact with students and working life that development takes place and that no bureaucratic organization must be created to increase the development of national and regional skills needs (Kunnskapsdepartementet, 2023a).

INN's strategy provides limited detail regarding the organization of its frontline operations. However, it emphasizes the importance of maintaining close proximity between the university college and external partners, with an emphasis on enhancing employee competencies to collaborate effectively with these partners (INN, 2021).

It seems that INN may lack a cohesive structure for tasks involving direct interaction with CPD students and stakeholders in the workforce and society. There appears to be ambiguity regarding the distribution of responsibilities within INN. Consequently, it could be argued that units like SELL, equipped with requisite expertise, could serve as an operational arm to manage these tasks on behalf of the educational institution. Such a setup could play a crucial role in meeting the authorities' requirements for proximity, accessibility, and bolstering trust at the frontline.

Externally Funded Activities are Organized in Separate Units

The Universities and University Colleges Act does not provide any guidelines on the internal organization of the institutions when it comes to lifelong learning and CPD (Kunnskapsdepartementet, 2005). However, all externally funded activities, i.e. activities that are not funded by state transfers for ordinary education, which are regulated by the Regulations for Contributions and Contract Funding (BOA regulations in Norwegian) (Kunnskapsdepartementet, 2013), must be separate from ordinary activities in financial terms.

As mentioned in the section above, the Ministry of Education and Research specifies through the 2024 Letter of Allocation 2024 that the institutions should

have a review of their own organization with the aim of giving employees in the first line increased confidence, and furthermore that no bureaucratic organization must be created to develop and offer national and regional competence needs (Kunnskapsdepartementet, 2023a).

We believe this is a signal that it is important to find an organization internally that has resources and focus on the CPD area and that has the right expertise and can quickly respond to demand from working life.

INN's strategy says little about how the work on lifelong learning is to be organized, but it is stated that there should be a short distance between the university college and external partners and that the employees at the university college should strengthen their competence to collaborate with external partners (INN, 2021). Furthermore, we see from the organization of INN that the scope and organization of these activities varies greatly at each faculty (INN, 2024b).

We contend that this reinforces the notion that activities focused on continuing and further education are best centralized within a distinct organizational and financial unit, akin to SELL's current structure. Such a unit would offer greater transparency and clarity, facilitated by its specialized and operational approach in shouldering this responsibility on behalf of the institution, while collaborating closely with academic environments.

An important point in the NIFU report on CPD offers in Norway by Tømte et al. (2015), is also the demand from working life for interdisciplinary programs, i.e. programs that are composed of subjects across the way educational institutions have often organized their academic environments and faculties. An apparatus that takes care of this contact internally is also specified as central (Tømte et al., 2015).

At present, SELL does not have a mandate to look after the whole of INN, but many of the tasks could be more effectively covered by a unit that has the expertise and network that SELL possesses.

Interaction between Higher Education and Working Life

The white paper no 14 titled: *Outlook on the skills needs in Norway* expects higher education institutions to cooperate closely with local and regional authorities and working life on skills needs and the provision of undergraduate and postgraduate education. For INNs purposes, this will be executed through the Council for Cooperation with Working Life at INN (RSA[5] in Norwegian) or through participation in regional skills partnerships under the auspices of the county councils (Ministry of Education and Research, 2023).

As we've seen, the Official Norwegian Report 2019:2 titled: Future Competence Needs II – Challenges for Competence Policy (Kunnskapsdepartementet, 2019) provides guidelines for strengthened cooperation between higher education institutions and working life to help create more relevant study programs. This is a clear encouragement to work more specifically in the development of study programs, rather than in general and more overarching meeting places. This

[5]The purpose of the RSA is to strengthen and structure the university college's collaboration with working life, to ensure that research activities and the study portfolio are developed in line with society's needs, and are based on a relevant and updated knowledge base (HINN, 2024).

argument is also supported by the 2017 interim evaluation of the effect and impact of the Council for Cooperation with Working Life at INN (Tellmann et al., 2017). They conclude that the Council for Cooperation with Working Life at INN has had modest effects on the development of study programs at the institutions. It is highlighted as a main challenge that in the dialogue and in the meetings, much attention is paid to overall strategies and general status, and less to specific study programs and continuing education (Tellmann et al., 2017).

In the NIFU report on CPD offers in Norway from 2015, it is stated that the institutions need framework conditions, capacity and expertise to meet the needs of the labor market (Tømte et al., 2015).

Through the analysis, it becomes evident that there exist numerous established platforms facilitating interaction between institutions and the workforce, yet these often fail to yield tangible outcomes to address the skills development needs of working life. This underscores the necessity of persisting in targeted development initiatives aimed at enhancing continuing and further education to better serve skills development goals. However, this endeavor necessitates institutions to prioritize and possess the requisite expertise. Considering SELL's expertise and core responsibilities, a similar unit could serve as a pertinent and effective model for offering comprehensive solutions to address multifaceted challenges.

Summary of the Results in Relation to our Two Research Questions

In the following, we will focus on answering the study's two research questions:

RQ1: What are SELL's current key functions and activities?
RQ2: How can SELL bolster political agendas and address future workforce learning needs?

Research Question 1: What are SELL's Current Key Functions and Activities?

In the document analysis and in the presentation of results and discussions, we have focused on SELL's role, tasks, organization and competence.

For more than 30 years, SELL has had a central position at INN to develop and offer competence programs for working life, regionally and nationally, through flexible educational offerings for individuals and employees in companies. In line with educational and technological developments, SELL has further developed its expertise to fulfill SELL's core activities. Market knowledge and an understanding and knowledge of the needs of working life are central to SELL's ability to fulfill the faculty's and university college's strategy and overall political intentions. SELL has the expertise to take care of interdisciplinary initiatives demanded by working life by coordinating collaboration internally at INN (SELL, 2024d).

SELL appears to be able to safeguard the "one door in" principle for working life. In addition, they currently have a role as a development actor and academic coordinator, as well as people who have the network, experience and expertise to

develop CPD offerings in line with the needs of working life. This is called for in reports that analyze the status of CPD for working life (Tellmann et al., 2017; Tømte et al., 2015).

In comparison with similar units at other higher education institutions in Norway, for example from two of Norway's largest universities (NTNU, 2024; Universitetet i Agder, 2024), we find that SELL has to a greater extent played a development role with more extensive expertise in pedagogy and has thus worked on the holistic development of the competence projects together with the academic environments at the university college and organizations in working life (SELL, 2024e). Other units that can be compared with SELL are smaller in scope and are to a greater extent support units that specialize in more administrative tasks and marketing related to the educational offerings, while academic development and pedagogical facilitation take place at the departments and in the academic environments.

Research Question 2: How can SELL Bolster Political Agendas and Address Future Workforce learning needs?

SELL can be seen as an actor to fulfill political strategies on lifelong learning. In light of the document analysis, we have also looked at how SELL can help to fulfill political strategies and support the need for lifelong learning in the working life of the future. The review has provided a clear picture of how lifelong learning and continuing education at a strategic level are emphasized in documents, from the highest level of authority through the Universities and University Colleges Act (Kunnskapsdepartementet, 2005), White Papers (Ministry of Education and Research, 2022, 2023) and the Official Norwegian Report 2019:2, the 2024 Letter of Allocation to INN (Kunnskapsdepartementet, 2023a) down to an operational unit level such as SELL.

In our analysis, we have identified that the Universities and University Colleges Act gives higher education institutions a clear responsibility to take care of the task of lifelong learning and continuing education, but no guidelines are given on how this task should be solved at the institutions (Kunnskapsdepartementet, 2005).

Recent white papers on higher education and skills needs in working life emphasize increased access to flexible and decentralized education for more people and workplace learning throughout life to increase employment in Norway (Ministry of Education and Research, 2022, 2023).

The Official Norwegian Report 2019:2 titled: Future Competence Needs II – Challenges for Competence Policy states that a strengthening of the collaboration between educational institutions and working life is needed to develop more relevant study programs (Kunnskapsdepartementet, 2019), which supports the argument that educational institutions should have an apparatus such as SELL in the first line to take care of contact with working life and the development of tailor-made studies for skills development for individuals and companies. However, further consideration must be given to which meeting places are needed in order to achieve fruitful interaction.

The 2024 Letter of Allocation from the Ministry of Education and Research states that INN is to be a driving force for lifelong learning, and there is an expectation

that the university college will follow up and develop relevant CPD throughout Norway. It is specified that the first line should be given increased confidence as the closest contact with students and working and social life (Kunnskapsdepartementet, 2023a), which is an important role at SELL today (SELL, 2024d).

Lifelong learning is an important strategic objective at INN. The strategy at INN addresses the need for restructuring in working life due to various regional challenges, and INN is committed to ensuring access to education and learning throughout the lifecycle in collaboration with regional, national and international partners (INN, 2021).

However, there is a dearth of information and guidelines regarding the operationalization and structuring of an entity equipped to undertake this responsibility. Nonetheless, the aspiration for close collaboration between INN and external partners is underscored. The organization of tasks related to CPD, lifelong learning, and collaboration with the workforce at INN lacks a clear structure, with somewhat ambiguous delineations of responsibilities.

The response to the second research question, concerning how SELL contributes to fulfilling political strategies and supporting the need for lifelong learning in the future workforce, is rooted in insights gleaned from the first research question. This initial inquiry focuses on SELL's core operations, competencies, strategic trajectory, and an examination of the expectations set forth by governmental bodies within the education sector.

Through our deliberations, we consistently assert that SELL can indeed aid in fulfilling political strategies by bolstering lifelong learning in the future workforce. It achieves this through possessing the necessary expertise to discern and address the needs of the workforce, acting as a frontline liaison between the workforce and educational institutions to co-develop and implement competency programs. Additionally, SELL can undertake internal coordination efforts in response to demands for interdisciplinary education and boasts sufficient expertise in line with the Technological Pedagogical Content Knowledge (TPACK) model proposed by Mishra and Koehler (2006) to craft comprehensive competency programs.

Conclusions

In summary, this paper illuminates how higher education institutions, exemplified by units like SELL at INN, can play a proactive role in fostering lifelong learning, Continuing Professional Development (CPD) with the workforce and society. The aim is to foster knowledge enhancement within professional realms, aligning with overarching governmental goals for lifelong learning.

Through our study, we have investigated two research questions: RQ1: What are SELL's current key functions and activities? RQ2: How can SELL bolster political agendas and address future workforce learning needs?

We've addressed the two research questions using a document analysis, categorizing documents into three levels: 1) National authority documents encompassing overarching political policies, 2) Institutional documents featuring

guidelines derived from governmental directives, and 3) Unit-level documents providing guidance from within the institution.

Our study's findings offer compelling insights into how units like SELL within educational institutions can play a pivotal role in shaping lifelong learning initiatives for the future workforce.

We have seen that the Universities and University Colleges Act (Kunnskapsdepartementet, 2005) stipulates that the tasks of higher education institutions include lifelong learning and continuing education on an equal footing with six other key tasks. The two white papers (Ministry of Education and Research, 2022, 2023) and the Official Norwegian Report (Kunnskapsdepartementet, 2019) have highlighted the increased need for skills in working life and the need for the education sector to help increase the number of and access to study programs and make them flexible. The Ministry of Education and Research expect educational institutions to be drivers of lifelong learning through a first-line service for working life. INN has a lifelong learning enshrined in its strategy and an ambition for a short path to collaboration with external actors, but there is a lack of a clear structure or division of labor in the area.

SELL possesses the requisite expertise to design and deliver adaptable educational competency programs tailored to the needs of the workforce, both regionally and nationally. A profound understanding of market dynamics and the specific requirements of professional environments is crucial for SELL to effectively bolster governmental strategies and INN's overarching lifelong learning agenda for the future workforce.

Limitations

We have meticulously curated documents we deem pivotal to the research's validity, relevance, and potential to shed light on our investigative queries. Our scrutiny extends to questioning the pertinence and representativeness of these documents and their interpretations. While acknowledging that alternative selections could yield different outcomes, our focus on SELL unavoidably introduces some limitations.

Certain documents were excluded from our analysis due to irrelevance to our research questions, inadequate information, or lack of valuable insights. It's important to note that two of the authors have affiliations with SELL, having contributed significantly to competence initiatives over several years. While striving for objectivity, their familiarity with the organization, university structures, and political landscape enhances nuanced discussions and aids in answering the research questions.

Future Directions

Looking ahead, our broader review underscores the imperative for further research and evaluation on the management of lifelong learning and ongoing education, both within Norwegian higher education institutions and internationally for comparative analysis. However, we postulate that future research would benefit

from examining the effects of the described activities over a longer period of time. We also advocate for exploring and experimenting with collaborative models between educational institutions and the workforce to enhance effectiveness.

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Introducing Digital Technology in a Rural Classroom: One Teacher's Experience

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Digital technology (DT) does not come with a 'menu' of what teachers can select to transform their instructional practices; it is through use and reflection in/on practice that potential affordances are abstracted. Computer simulation (CS) as DT was explored through auto-ethnography, reflexivity, and action research. The findings of the study revealed that the use of DT when teaching is a sense-making process employed to respond to the contextual and situational demands of the concerned teacher. It is a dynamic and unpredictable situated practice that is focused on the emergent affordances resulting from the interface between technology and pedagogy. The aim is to craft a 'contextualized' technology-driven pedagogy to meet the teaching and learning needs of learners in rural schools. It is a professional learning activity that develops self-knowledge and skills that enrich the knowledge base of the individual teacher. Such knowledge contributes to practice innovation, where DT is adopted and adapted to make learning interesting and inclusive and where it engages learners in constructing their knowledge and developing skills to achieve set learning outcomes. The findings are more descriptive than prescriptive since teaching endeavours cannot be cloned but could assist other teachers who might be interested in using DT in their specific contexts.

Keywords: digital technology, learning, reflection, rural schools, teaching

Introduction

While the talk of the need to integrate digital technology (DT) into teaching and learning resonates and continues to reverberate within the school community, it remains largely rhetorical in rural schools. There is no interest or sustained effort to promote the integration of DT as a pedagogical tool (Botha et al., 2017). There appears to be a lack of digital leadership in rural schools on the part of principals. Much of the existing literature claims that the principal's digital leadership affects technology integration in schools (Greaves et al., 2010; Raman & Thannimalai, 2019). Thus, it is not perplexing and surprising that, despite the existence of three key education policies on information and communication technology (ICT), nothing substantial to reflect the appropriation and embodiment of such policies in teaching and learning has been observed, especially in rural schools (Vandeyar, 2021). The three education policies are the e-Education policy (Department of Education [DoE], 2004), the Guidelines for Teacher Training and Professional Development in ICT (Department of Basic Education [DBE], 2007), and the

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Professional Development Framework for Digital Learning (DBE, 2018). The e-Education policy was crafted to develop public schools as e-schools (by the year 2013), with the primary intention of improving teaching and learning in schools. The Guidelines for Teacher Training and Professional Development in ICT (DBE, 2007) stipulate information and communication technology (ICT) knowledge and skills as a prerequisite to effectively implement the national school-based curriculum, while the Professional Development Framework for Digital Learning (DBE, 2018), is aimed at developing teachers' digital skills, to promote and facilitate learning with ICT tools and digital resources.

Unfortunately, the e-Education policy has either found its way onto school shelves or is still swirling around in the clouds above without being implemented on the ground (Vandeyar, 2021). Unfortunately, the policy has suffered a stillbirth in its implementation in rural schools. Arguably, the lack of digital leadership is hampering visionary planning, excellence in professional practice, the creation of a digital age learning culture, and system improvement (AlAjmi, 2022; International Society for Technology in Education [ISTE], 2014), despite teachers being aware of the benign ability of DT to transform instructional practices. Thus, the environment is inherently unsupportive and disempowering, hampering the adoption and integration of DT into mainstream curricula. This promotes an attitude of recalcitrance, with teachers still stubbornly clinging to dry, replicative traditional teaching practices that have been encultured in schools (Ng'ambi et al., 2014). This is not surprising, as research confirms that there is a general disinterest among some South African teachers in using technology in the classroom (Dlamini, 2018; Mlambo et al., 2020). Resource constraints in rural schools are acknowledged, and their effects on pedagogy have remained detrimental to both learner experiences and outcomes (du Plessis & Letshwene, 2020). Research does, however, offer a glimmer of hope, as there is evidence that digital technology can mitigate some of the challenges brought about by a lack of teaching and learning materials (Wu et al., 2022). Consequently, the question arises of what it means for rural (science) teachers to adopt and adapt DT to transform the current 'aerosol' approach to instruction (where learners are 'sprayed' with information in the hope that it 'sticks' in their minds).

The research question that the larger study reported on here sought to answer is: What were the salient dimensions of the researcher's instructional practice when teaching with computer simulations (CS) in a rural classroom? Inherent in the research question is the importance of rural science teachers' reflection on different issues, such as the influence that DT has on teachers' thinking and actions, the way in which content is transformed in order to be accessible to learners, or how it can be used to engage learners and how they can appropriate the pedagogical affordances (both perceivable and unperceivable) presented by DT. Therefore, the objective is to identify the emergent pedagogical affordances that enable transformative actions that support learning. To that end, teacher agency plays a critical role in noticing, selecting, and utilizing those affordances.

The research question was pertinent when I adopted and integrated CS (for the first time) in my instructional practice in a rural classroom – a unique context plagued by multifaceted exigent challenges. I believe learning is a process that

must be intentionally and purposefully cultivated through opportunities to actively shape the content so that there are no interruptions between how learners access and appropriate the content. A well-connected network of scientific ideas and purposeful understanding will not develop by chance for learners; it has to be pursued actively through the use of appropriate teaching strategies by creating optimal conditions and offering mediating tools in the learning environment (Kokkonen et al., 2022). This aligns with the expectations of the DBE that learning materials should be organised in such a manner that it is coherent and logical to facilitate learner comprehension (DBE, 2011). Therefore, I conducted an inquiry into my professional practice with the intention of using CS to author new professional practices in a context where performative (as opposed to participative) pedagogies are encouraged and promoted. However, I was not fully aware of the severity of learners' deeply rooted familiarity with the conventional mode of teaching. While I believe learners would embrace the opportunity to learn with CS, I found that they needed time to adjust to this new way of learning, given their limited experience with such learning environments. In the broader context of teaching, Russell (2007) warns teachers not to expect too much too soon. The challenge that confronted me was negotiating and accounting for my instructional approach in the broader context of transmissive and performative pedagogies to which my learners were accustomed.

It is a common practice within the circuits in different districts of education departments to set targets for schools to achieve. In a recent study, teachers lamented that the DBE is more concerned with the number of learners passing than with the quality of the passes and does everything in its power to ensure that more learners pass (du Plessis & Letshwene, 2020). The deficiency of such an emphasis reduces teaching to a relatively simple process of teachers enacting particular strategies or teaching moves that will result in a linear progression of improved learner achievement, as measured by high-stakes standardized tests (Warner, 2016). In the circuit where the study was carried out, schools were given a performance average pass rate of 75 percent, which was the average performance required of learners at a given school. Any school performing below this threshold was labelled as underperforming. This is problematic, as the stigma of being labelled thus puts the school in the crosshairs of the DBE and drives them to adopt pedagogies to promote a performative learning culture. This effectively means that the ball is in the teachers' court, and they have to drill learners to pass without effective learning taking place. As for learners, they adopt a 'flight mode,' in which they are only supposed to follow instructions. This 'pass rate syndrome' is turning schools in South Africa into mass-production factories that churn out Matric graduates who meet set requirements/standards. Those who fail to meet the standard can re-write or attend a vocational college. Many, however, give up.

Teaching with Digital Technology in Rural Schools

Digital technology is a term used to refer to all devices and programmes/ applications connected with the use of a computer. There is a paucity of research on how schools in rural areas integrate such technologies into the mainstream

curriculum. Whilst research on rural schools has focussed on teachers' conceptions of teaching and learning (Mafunganyika & Nkambule, 2018), rural teachers' development of PCK for inquiry-based teaching (Shinana et al., 2021), rural teachers' experience of problem-based teaching (Osman & Kriek, 2021), rural teachers' management of discipline (Lunga et al., 2021), learners' experience of learning in rural areas (Moloi et al., 2010), and parental involvement to enhance learner achievement in rural areas (Zenda, 2020), not much has been researched on how teachers in rural ecologies adopt and integrate DT into their practice. Not much is known about how DT is integrated in rural areas to enhance meaningful learning, considering the fact that these contexts are both constrictive and unsupportive (Jita & Munje, 2020). For that reason, it is important to view DT integration by focusing on the effective use of technology to transform how teaching is currently done in rural schools. Arguably, the most effective use of DT transcends beyond using it in fits and starts. It requires fundamental changes in how teaching and learning currently occur in schools. The challenge remains that teachers need to orchestrate instructional approaches that "improve science knowledge and skills; demonstrate the relevance of science to society and the intellectual life of a student; illustrate the changing and uncertain nature of science; develop students' critical thinking skills; improve speaking and writing skills; and motivate students to like science and to want to learn more" (Druger, 2002, p. 148). Hence, more research is needed to explore and understand how DT is transforming rural teachers' thinking and instructional practices to achieve this goal. The integration of DT is not uniform (considering the diverse contexts in which teachers work) and cannot be cloned. This view is rooted in the Deweyan (Dewey, 1938) perspective, which asserts that two or more teachers could live the same experience yet take away different meanings from it. Teachers create different personal meanings from new experiences and interactions (Craig, 2018). Hence, the diverse and idiosyncratic ways rural teachers use DT will help illuminate the finer nuances so as not to miss the enablers and constraints of DT in these contexts where the policy on the integration of DT has remained invisible.

The adoption and integration of DT within these ecologies are both critical and long overdue. In such contexts, science teachers' instructional intentions have remained heavily focused on content coverage and personal feelings and only minimally involve learners (Erdmann et al., 2020). Hence, low levels of learner achievement have been reported, as well as very high dropout rates (Spaull, 2015) resulting from poor teaching and learning experiences, which has not changed significantly over the post-apartheid era (Mlachila & Moeletsi, 2019). Disruptive behaviours, teenage pregnancy, alcohol, and other drug abuse, and the disturbance of classroom activities – all of which affect teaching and learning – have increasingly been observed in schools (Banda & Mweemba, 2016; Marais & Meier, 2010; Mgwangqa & Lawrence, 2008; Reyneke, 2013; Sun & Shek, 2012). Research suggests that teachers in schools with large proportions of learners from disadvantaged backgrounds, which such learners are more likely to attend, are more inclined to use the traditional teaching approaches (Bernstein, 2000). Thus, it is evident that learners in rural schools will lack access to enriching experiences that are critical for developing their science knowledge and skills. Compared to

learners from affluent and resourced districts, the learning needs of the majority of learners from rural schools are not prioritized.

However, some of rural schools' challenges can be mitigated by teachers' collective responsiveness to adopting and integrating DT into instructional practice. The potential of DT affordances to transform the quality of teaching and learning experiences in science classrooms in South Africa (and elsewhere) has been raised extensively in the literature (Gui et al., 2018; Kaur & Singh, 2020; Umugiraneza et al., 2018). Actually, gaps in learning outcomes have been reported between those with access to DT and those without, within and between countries (Dibapile, 2012; Durowoju & Onuka, 2015). From a social justice perspective, the adoption and integration of DT in rural ecologies is viewed as a process aimed at intentionally disrupting the hegemonic practices that contribute to and perpetuate the production of educational and wider social inequalities. This approach distances itself from conventional transmissive approaches by appropriating the pedagogical affordances of technology to engage learners as legitimate participants in an interactive way and provide learning activities they can relate to their personal experiences and prior knowledge, thereby making school science relevant. Hence, how rural teachers orchestrate socially just pedagogic practices, mediated with DT, is worth researching, given the "unforgiving complexity of [such] teaching" (Cochran-Smith, 2003, p. 3). The characterization of rural teachers' use of DT in instructional practice has been overlooked in the literature on science education despite its importance in an era characterized by instructional change reform efforts.

Computer simulation (CS) is one example of a science-specific DT that was used in this study. A CS is a computer-operated application that models the behaviour of scientific phenomena. It abstracts and simplifies those phenomena by focusing on key features to explain and predict behaviour. Importantly, the application illustrates how the dynamic macro-features of phenomena are related to the micro-features. The computer application is thus robust, with interactive affordances that allow teacher–learner engagement with the application. Because of the challenges encountered in rural schools, CS as a resource can be used in science lessons without the fear of breakage or depletion by learners or harm to learners. Most CS are available freely online and can be downloaded and used offline. This is an advantage to schools in rural areas with connectivity problems, and schools do not have budgets for internet connection.

Although many teachers have knowledge and experience of CS, this does not suggest that CS will be integrated successfully into their teaching practice (So & Kim, 2009). Both anecdotal evidence and recent research show that simulation implementation in the science classroom is slow and challenging, especially in rural schools (Bo et al., 2018). These challenges emanate from the complexity of adopting, adapting, and integrating them into instructional practice for specific audiences and contexts (Kriek & Coetzee, 2021).

The characterization of teachers' thinking when using CS is lacking despite its importance in an era where the integration of technology in instructional practice is vital. Research that takes account of the preferences and characteristics of (rural) teachers and their epistemological beliefs (Kearney et al., 2012) is

critical for establishing strong pedagogical practices that will not remain ephemeral. Thus, the lack of a strong research-based approach to teaching and learning with CS has the potential to hinder the adoption and customization of CS within rural pedagogy.

To answer the research question, these three main ideas are employed: (a) self-reflexivity, drawing on the understanding that reflexivity acknowledges that we shape and make meaning about our world from within (Ripamonti et al., 2016) and the conceptualization of reflexivity as reflection with social and scientific foundations that leads to social change (Mora, 2018); (b) autoethnography as a methodology that values personal experiences, which are deemed central to meaning-making and reinterpreting the relationship among actors, events, and contexts (Boje, 2001); and (c) action research as an ethical commitment to improving society (i.e., make it more just), ourselves (that we may become more conscious of our responsibility as members of a democratic society), and ultimately our shared lives (i.e., building community) (Holly & Kasten, 2001).

Reflexivity

Reflexivity and reflection are not synonymous; hence, it is critical to distinguish between the two terms. While there is reflection during reflexivity, the latter is more complex, involving practitioners taking a different ontological position of not just reflecting on issues from an objective distant stance but recognizing reflexively their role as embedded in the flow of events and in constituting social and organizational realities in ways they may be unaware of (Ripamonti et al., 2016). Through reflexivity, practitioners are encouraged to question and recognize their pedagogical responsibilities by becoming more conscious of how their assumptions, beliefs, and actions shape "realities" and create possibilities for moving on in the situations they face.

In the current study, reflexivity was employed because of the need to ground my ideas on the deep understanding of my situation, contexts, and participants as a requirement/obligatory step in engaging in transformative change (Mora, 2018). Importantly, reflexivity enables the practitioner to develop and learn through reasoned reflection on epiphanies – remembered moments perceived to have significantly impacted the trajectory of his/her life (Bochner & Ellis, 1992; Denzin, 1989), and analyzing how others perceive the event. This is critical, considering that these epiphanies reveal the ways in which a person could negotiate 'intense situations' and 'effects that linger long after a crucial incident is supposedly finished' (Bochner, 1984, p. 595).

Autoethnography

Autoethnography is a narrative method of inquiry that priviledges the individual practitioner as s/he seeks to find out about him/herself and his/her relationship with the research topic (Muncey, 2010; Richardson, 2000). In this tradition, the process of writing in a highly personalized style is emphasized as a form of discovery, drawing on the experiences of the practitioner to extend understanding

of a societal phenomenon (Wall, 2006). The autoethnographic approach is often used in first-person action research projects (Sykes & Treleaven, 2009), as an autobiographical genre of research that displays multiple layers of consciousness, connecting the personal to the cultural (Ripamonti et al., 2016).

In the current study, the use of autoethnography was deemed necessary to produce meaningful, accessible, and evocative research grounded in personal experience – research that would sensitize readers to the issues confronting teachers in rural areas, experiences which are usually given lip service and to forms of representation that engender empathy in those teachers. What rural teachers do is often under-recognized in existing literature dealing with the quality of education. Autoethnography acknowledges and accommodates subjectivity, emotionality, and the researcher's influence on research rather than hiding from these matters or assuming they do not exist (Ellis et al., 2010). Practitioners rely on autoethnographic accounts, diaries, or field notes, enabling them to reflect and question their practice. Thus, narrative, discursive, or ethnographic methods are regarded as fruitful ways of generating knowledge.

Action Research

Action research (AR) is situated within a range of narrative research approaches where inquiry is made to address 'issues of concern to individuals and communities in the everyday conduct of their lives' (Reason, 2006, p. 191). Thus, embedded within AR is a commitment to social justice, defined in terms of equal access for all learners to benefit socially and economically from education as a positional good (Lingard, 2005; Reay, 2012). Furthermore, it includes equal access to experiencing the pleasure and enjoyment of learning in coming to understand something that is difficult yet worthwhile, for example, 'discovering what it is to generate intellectual insights or what it is to read critically' (Griffiths, 2012, p. 664). Thus, AR is foregrounded in practices that seek to change cultural practices and discourses that contribute to producing educational and wider social inequalities. AR brings transformation. Inherent within AR is an ethos that seeks to redress and empower the disadvantaged/ marginalised through socially just pedagogies. Without this dimension, AR becomes like any other research in which researchers pontificate about a field from the presumed position of 'expert' (Mora, 2018).

In this study, AR was the medium used to initiate a transformation in teaching and learning using DT.

Data Collection

Three types of research reporting underpinning narrative inquiry were used: (a) a descriptive report of a privately constructed self-account in its original narrated form, (b) a recounting of a dialogically generated narrative (or set of narratives) in story form, and (c) a storied account of an experience constructed from interviews, written reports, observations, and artifacts (Hoshmand, 2005). The

data were collected from reflective journals, focus group discussions, and informal communications with colleagues and learners. The credibility of the findings was enhanced by triangulating the data sources. The data were collected over a period of three years, which enabled meta-reflection by the researchers. Meta-reflection is typical of a meta-cognitive mindset; it entails reflecting on a personal reflection from a scholarly point of view. I hoped that by persistent observation and prolonged engagement (Guba & Lincoln, 1989), I would develop a deeper understanding of the use of CS from an 'insider' perspective in practical ways that would render knowledge utilization for interested colleagues and future teachers. Thus, I hoped not only to construct public knowledge of the practice (LaBoskey, 2004) but also contextual knowledge for informing my signature teaching and contributing to professional knowledge about the intricacies of teaching with CS in a rural context.

Data Analysis

The data were analyzed not to develop a theory but rather to illustrate how past experiences can shape future experiences. In Clandinin and Rosicks' (2007) view, 'lived experiences [are] a source of important knowledge and understanding (p. 42). One major way in which experience can be captured and communicated is through the narrative approach. This study is grounded in the perspective that there should be a shift of the research community's attention from propositional knowledge (what teachers should know and do according to experts in the field) to non-propositional knowledge (what teachers know and do, narrated in their terms, using their own voices and word choices) (Craig, 2018). This is important considering the fault lines that exist between theory and practice. Two themes emerged from the data about the salient dimensions of my instructional practice when teaching with CS: (1) seeking a mediated dialogical approach to learning and (2) avoiding putting blinkers on the learners' minds.

Findings

Seeking a Mediated Dialogical Approach to Learning

Seeking a mediated dialogical approach to learning was a frequently recurring theme of my efforts to teach with CS, where the teacher and learners explored and generated ideas and questions together. The simulations created the contextual setting to mobilize and use a mediated dialogue. Thus, a teacher-technology-mediated dialogue was realized, which can be contrasted to a teacher-mediated dialogue from a distributed cognition perspective that the ability to interact meaningfully with tools expands one's mental capacity. We make this distinction because ample research exists on teacher-mediated dialogue (see Kumpulainen & Rajala, 2017; Resnick et al., 2015; van der Linden & Renshaw, 2004), but less is

known about teacher–technology-mediated dialogue. In my reflective journal, I wrote:

> *[CS] are good graphical representations of scientific phenomena in which the teacher can engage learners to verbalise their thoughts, ideas and feelings during a reflective discussion. CS create and stimulate an interactional space for learners and the teacher to talk and think together. I am excited about this, because it eliminates the domination of my voice as the teacher in the class… They provide an environment for exploration of science concepts through dialogue and questioning opportunities.* (Reflective journal, August 2015)

This excerpt brings out the following features of teacher-technology-mediated dialogue: they are *cumulative* (the teacher and learners build on their own and each other's ideas, chaining them into coherent lines of thinking and inquiry), s*upportive* (learners articulate their ideas freely, without the fear of embarrassment over 'wrong' answers, and support each other to reach common understandings), *purposeful* (teachers plan and facilitate dialogic teaching with educational goals in mind), *collective* (teachers and learners address learning tasks together), and *reciprocal* (teachers and learners listen to one another, share ideas and consider alternative viewpoints) (Alexander, 2008). Notably, teacher-technology-mediated dialogue imposes no demarcated limits (learners are not constrained/limited to understand from the perspective of the teacher or textbook author) and supports the development of science language (learners are allowed to express their ideas in their own words).

During the lessons, I found myself assuming a number of roles necessitated by the various actions enabled by the use of CS. My roles shifted between being a facilitator, guide, navigator, and co-learner, encouraging learners to take responsibility for learning and providing opportunities to develop their learning skills. As I traversed between the roles, I had an opportunity to evaluate my thinking and that of the learners and reflect on that. This opportunity determined whether or not I could proceed with the lesson. How these roles interacted, interwoven with self, contributed to the growing tapestry of teaching with digital technology. I was able to reframe my teaching, moving from clashing tales of triumph and tragedy to focusing on how to engage learners in a dialogue so that they could appropriate the epistemic benefits of CS. At the same time, learners had to adjust and assume new learning roles and responsibilities that went beyond listening and taking notes and were encouraged to take control of their learning. The following excerpt was provided by a learner:

> *…he provides both a great mix of listening, speaking and practical learning activities. As a learner you feel pushed to learn and try to gain valuable feedback that helps you to improve. He paces the class just right, so you feel challenged but not overwhelmed. So, in other classes you just read from a textbook but in his classes he asks questions and gets the learners to respond, which are both fun and promote faster learning.* (Wanga)

The approach of adopting a dialogical dimension was both intentionally and driven by three imperatives to help learners build connections. As Gee (2003, p.

73) suggested, '[i]t is the connections or associations that people make among their experiences, that are crucial to learning, thinking, and problem solving'.

- Promoting and Developing Science Language Among Learners

One of the general aims of the DBE's (2011) Curriculum Assessment and Planning Statement (CAPS) (section 1.3d) is to produce learners who are able to communicate effectively using visual, symbolic, and/or language skills in various modes. Related to this aim is the ability to collect, analyze, organize, and critically evaluate information (*ibid*). Thus, there is a need to provide an open space for learners to publicly share and revise ideas without fear that their thinking might be ridiculed or dismissed, thereby stifling learner talk. Talk is evidence of, and a tool for, scientific sense-making and scientific sense-making in itself (Ryu & Sikorski, 2019).

- Engaging Learners as Legitimate Participants in the Learning Process

While not explicitly expressed in the literature on teaching, one of the roles of teachers is to engage learners as legitimate participants. This perspective constrains teachers not to treat learners as 'empty vessels' to be filled with information. Such controlling teaching promotes extrinsic motivation, not intrinsic motivation, which is a crucial aspect of autonomy. Autonomy is the agentic ability to be self-governed with self-directed and determined action, whereas being controlled involves responding under direction or coercion. The learner's comment that '… *you feel pushed to learn and try to gain valuable feedback that helps you to improve*' intimates that engaging learners as legitimate participants develop in them autonomous motivation, which is defined as engaging in an activity for interest and enjoyment, or a sense of personal value and importance (Jiang et al., 2019).

- Valuing Learners' Contributions

The responses by learners, when they observe a phenomenon differ from when they merely imagine the phenomenon. Learners were able to comprehend and communicate the information represented by the CS graphics, and they demonstrated visual literacy skills. Evidence suggests that discussions that are computer-mediated elicit substantive comments from learners, which might require the reshaping, re-accentuation, and reorganisation of ideas (Chi et al., 2017). I noted in my reflective journal:

> *Learners were able to give valid descriptions of the magnetic field around the current-carrying conductors. One learner was able to give a description which I had not anticipated. He said that the field was non-uniform, as evidenced by the fact that the circles were not equidistant, with the field lines near the conductor very close together while those far from the conductor were farther apart. He even suggested that the field was, therefore, stronger near the conductor, while weak far away from the conductor.* (Reflective journal, August 2015)

I valued learner contributions for two epistemic reasons: 1) it was meant to be a process in which 'knowing' was to be developed in individual learners – I wanted them to develop the 'epistemologies for' rather than the 'epistemologies of' science (Ko & Krist, 2019, p. 980). From a disciplinary perspective, the learners' comments were as valid as those written in the textbook. Their remarks

were infused with authentic terms (e.g., non-uniform, equidistant) and expressions not provided by the teacher or the textbook. It was a substantive comment that showed that the learner could interpret the features of the magnetic field – evidence of learning appropriation. 2) by encouraging learners to express themselves, I wanted them to value their personal constructions of meaning, just as they would the textbook. One learner explained why he enjoyed my lessons, '*he is a good communicator and… he likes to hear our opinions…*' (Focus group discussion [FDG], 2015). I took the word 'opinion' to mean their contributions. Evidence shows that most learners unquestioningly accept what appears in the textbook or what the teacher says (Teo, 2016). Such an attitude or mind frame develops when learners are 'filled' with information. Costa et al. (2020) concur that focusing on mastering subject-area knowledge alone is insufficient for capacitating learners with the ability to think critically, demonstrate creativity and imagination, communicate effectively using various media, work collaboratively with others, and self-direct their lifelong learning.

Avoiding Putting Blinkers on the Learners' Minds

In my teaching efforts, I was not preoccupied with dictating notes to learners (which is the custom learning activity in most rural schools). Such an ontological perspective was designed to make the instructional space more inclusive, requiring 'that we see ourselves and our learners as individuals with social identities, backgrounds, prior knowledge, skills, strengths, challenges, needs, subjectivities, and goals' (Loya, 2021, p. 2). These aspects are important to consider when planning, implementing, and assessing our teaching and learners' learning. In my view, handing out prepared notes would be like putting blinkers on the learners' minds, as that would constrain them to understand concepts from the teacher's perspective, thus limiting their locus of cognition. Unsurprisingly, for learners, cramming offered both an escape route and an alternative way to 'temporary understanding'[6] (i.e., convenience learning). Temporary understanding sees the knowledge which learners require for assessment activities for that particular moment, hence it is knowledge for convenience. Learners have no intention or do not expect to use that knowledge beyond the walls of the classroom or after the examination. In fact, the learners intimated that they were highly inclined to reproduce passages of text that they read in their textbooks in the examinations. They would conceivably do the same with the notes they are given. Below are excerpts from learners on the use of CS in their learning:

> *So, the computer simulations make it easy to understand better as opposed to reading from the textbook. You are able to describe what you have seen in your own words. When you read from a textbook it is easy […] to cram the whole passage that you are reading and reproduce it in the examination.* (Khezwo)

[6]This term was motivated by an acronym, CPF (cram, pass and forget), which learners in rural schools tend to use. It indicates that learners were not concerned about understanding, only in how to use information/knowledge without expending any mental effort. Such information was solely required for the sake of passing tests/examinations.

> *For example, a learner gets to understand what they are learning without cramming to pass. Also, by using simulations it […] helped us to understand the topics much better, since we got to see what was taught in action. A learner always has the chance to write what he or she understood and not what she crammed.* (Melton)
> *… encouraged thinking out of the box and understanding what is taught in-depth rather than cramming, so that in the future if you come across those learning aspects, you'll be able to tackle them even when you are alone. Furthermore, he did not bombard us with a lot of information at once, he aimed to make us all understand one concept at a time, provided us with great examples to work on, because he understood that all learners can learn and succeed, but not in the same way and not in the same day. In addition, I was encouraged to always come to the next lesson prepared, influenced by the fact that he was always prepared, and it was evident that he knew what he was doing.* (Motho)

By not putting blinkers on the learners' minds, they were able to understand better without cramming, thinking out of the box, and coming to the next lesson prepared. However, what was common in the learners' comments was avoiding the practice of cramming – something many learners use to learn, unfortunately. While this finding cannot be generalized, as the learners' comments showed, they are driven to cramming by teaching approaches in which the teacher's voice dominates. Learners would not spend their energy cramming if they were allowed to develop their understanding without science ideas being forced down their throats in the form of prepared notes. Learners need the intellectual stimulus of engaging in critical thinking so that information is not blandly accepted and simply memorized.

Discussion

Despite the lack of teaching and learning resources in schools in rural areas, the small changes, though not revolutionary, brought by the use of digital technology are significant to consider. Thus, teachers wishing to engage learners in meaningful learning realize the possibility of orchestrating transformative instructional practices beyond conventional transmission teaching. Hence, there is a need for concerted efforts on the part of teachers as agents of change and designers who integrate DT in their instructional practices to redress the experience of marginality that learners in rural schools experience due to the various challenges besetting these contexts. However, incorporating DT into instructional practice requires an understanding that extra energy will have to be expended and choices defended because the school culture and climate remain resistant to change or reform teaching practices (Boyle et al., 2013).

Seeking to introduce DT into classroom practice is not an event but a process that teachers engage in, which results in their professional development or growth. In this regard, AR is a mechanism for professional development, bringing about change/innovation in practice. We propose that school managers encourage teachers to become action researchers. As Arrifin et al. (2018) note, effective teachers in Malaysia are those who carry out research in their classrooms, using the ensuing practical/self-knowledge to address learners' contextual needs. The practical/self-

knowledge developed contributes to the knowledge base of teaching and also to organizational knowledge, which can innovate instructional practices (Nonaka et al., 2006; Spender, 1996). Notably lacking in the literature is the mechanism of how such self-knowledge can be tapped into to improve the system.

The affordances presented by digital technology challenge the conventional teacher's role as an exclusive source and definitive authority of knowledge. The teacher and his/her learners must interact with DT to co-construct knowledge through dialogue. Therefore, the use of CS extends beyond it being regarded as an 'add-on' or tool to support 'the way students learn from classroom teachers' (Wang et al., 2014, p. 101) to a tool to 'learn with' (Salomon et al., 1991). Importantly, a precursor to using CS for teaching is for teachers first to be aware of the pedagogical affordances thereof. Such affordances do not come labelled with the technology but are rather abstractions of practice constructed as individual teachers reflect on their use in different contexts. Thus, affordances are teachers' personal constructions by reflexively taking an intentional stance in evaluating themselves and how they interact with CS with their learners. The findings suggest that there is latent potential in using CS to mediate instructional dialogue as an approach to teaching physical sciences, especially in rural contexts.

The features of a mediated dialogic teaching resource and collective and cumulative teaching and learning experiences can potentially improve learning outcomes in rural schools. A critical function of dialogic classroom interaction is communal understanding through collective meaning-making and connection-building (Littleton, 2010). Thus, the focus is not on the instantaneous absorption of knowledge but rather on the use of technology as a 'mediating artefact' (Engeström, 2001, p. 73) in specific activities and their goals which can be seen to contribute to the greater whole. The affordance of using CS as a mediating artefact supports the teacher in making pedagogical decisions or taking actions to engage learners in active learning rather than them being passive listeners. On average, active learning was found to lead to higher examination scores and lower failure rates for all learners compared to learners taught via traditional teaching methods (Freeman et al., 2014).

The primary phenomenon of significance in this study is the shift in the thinking and actions of the teacher brought about by the use of CS in teaching and learning, a shift from focusing on the designed/planned but rather the emerging classroom curriculum. The use of technology stimulated actions where I became intentional and deliberate in my attempt to transform science content in ways accessible and comprehendible to learners. Through the use of CSs, I learned to be reflective, thoughtful, purposeful, and deliberate in my decisions, actions, and questions. CS presented cues and affordances to mitigate the practical dilemmas I faced in trying to carry out purposeful actions in a rural setting. Learning conditions in schools in rural schools are incongruous with meaningful learning. Thus, learners are not in a better position to learn with a sense of belonging and well-being. Therefore, intentional teaching as an immersion pedagogy creates learning opportunities and discourse so that teachers cognitively engage learners in meaningful and authentic conversations to develop and nurture habits of mind. In increasingly diverse and inclusive classrooms, teachers need professional learning

to create mediated spaces where learners with varied social identities and intersectionalities are not constrained but feel welcomed, represented, and supported to learn successfully (Loya, 2021). Hence, predetermining learning experiences is an attempt to provide universal, value-free, rational, objective, and detached ways of teaching and learning (ibid). Such an axiological stance dominates the power and priviledges of the teacher, which could lead to the exclusion of the voices of less-priviledged groups (Alcoff, 2001), where learners are framed as victims needing to be saved.

The use of CS can create interactional learning spaces and engage learners from different backgrounds, with different abilities, and cultural and social dynamics. In this learning space, learners are expected to be not only receivers of knowledge but also co-constructors. Such an epistemological stance requires teachers to shift and dismantle historical perspectives that expect learners merely to be recipients of the information. Whenever content is clearly organized and presented, it is the cooperative responsibility of learners to construct meaning on their own. They need to establish links between interrelated concepts. This network of concepts exhibits the richness in the connectedness of scientific ideas, which enhances meaning-making (Mudadigwa & Msimanga, 2019). However, constructing meaning by accessing isolated content acquired through dictation and rote learning is problematic, as a linear outline is limited in the scope of the relationship of a concept with other scientific concepts. Such knowledge might be useful for recalling low-level tasks but not for conceptual understanding (Taber, 2014). While it is possible that such information can be retrieved, it is difficult for learners to apply rote-learned knowledge to solve problems in new contexts (Novak, 2002). Therefore, cramming only caters to immediate outcomes, not the sustainable acquisition of content knowledge.

The integration of DT in a rural classroom is a complex, recursive, and often rhizomatic process that involves a matrix of interaction between the teacher, learners, content, and the learning environment. Understanding the relationship between the elements in the interaction matrix forms the frame of reference that shapes how our ontology, epistemology, and axiology inform instruction. Our instruction responds to and upholds certain realities, ways of knowing, and values, and the ways in which we facilitate their inclusion in our learning environments (Loya, 2021). In this process, teachers learn by developing and internalizing patterns of professional thinking from opportunities created through teaching and learning. By reflecting on the thinking of their thinking and actions, teachers can make explicit the ways in which they support their learners' learning and engagement. Thus, DT integration involves a paradigm shift, a way of thinking that requires teachers to be conscious, interested, and committed to turning their attention away from content and focusing on the processes of how that content can be transformed to enable meaningful learning through which positive outcomes are attained.

In our view, it is imperative for teachers to understand rural learners' environment and select relevant DT by integrating it in such a way that learners are actively engaged. Teachers must facilitate understanding by being aware of the affordances and the correct use of DT. One way of embarking on this process is to

become action researchers, as in this way, teachers reflect on their instructional practices, a critical process in teacher's pedagogical reasoning and action. Through reflection, teachers develop new comprehensions- insights into new ways to orchestrate and support learners' learning and engagement. New comprehensions are the basis on which the abstraction of instructional practices is anchored.

Conclusion

While the lack of teaching and learning resources in rural schools has created pathologies of practice, resulting in collateral damage to learning outcomes, the use of DT has a consequential effect on teachers' instructional practices. Teaching with DT enables a teacher to exercise agency, going beyond the impediments presented by the local context to orchestrate instructional practices that respond to their situational demands. Critical in helping the teacher exercise agency was the autonomy that allowed him to author his signature teaching by reflecting reflexively. In a sense, teaching with DT was a professional learning opportunity that was empowering in that it enabled the teacher to reform his pedagogy in response to the context of teaching, making him a critical agent in bringing change to the field of science education. Teaching with DT was a sense-making process that resulted in pedagogical shifts where the focus moved from content to seeking to establish meaningful and authentic relationships with learners. This was achieved through *a mediated dialogical approach to learning, which involved promoting and developing science language among learners, engaging learners as legitimate participants in the learning process while valuing their contributions.* The interactions presented the teacher with the space/opportunity to assume different roles to address the arising/ varying learning needs of learners without putting blinkers on how they understand the content. This is critical since learners in rural schools have long been treated as empty vessels to be filled with information rather than being seen as individuals with agentic roles in the knowledge-creation process. This complex process goes beyond ticking boxes and cannot be expressed easily as a linear function. The use of DT in teaching transforms the process and teacher–learner interactions. The potential of DT to effect this is premised on the teacher developing the knowledge and skills to appropriate such pedagogical affordance. The quality of learning experiences is coterminous with the quality of teacher–learner interactions. For the teacher, teaching with DT is professional learning, a process of seeking new comprehensions/insights on how to appropriate pedagogical affordances to enhance learning, thereby contributing to the ongoing improvement of teachers' knowledge and practice by evolving and extending the boundaries of instructional practice. The way in which DT is implemented in class reflects or draws from distinct epistemological, ontological, and axiological perspectives of teaching.

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Using Classical Rhetoric in the Age of AI: A Study on Waltzer, Cox, and Heyman's Study "Testing the Ability of Teachers and Students to Differentiate between Essays Generated by ChatGPT and High School Students"

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This paper analyzes essay writing in AI (ChatGPT) and high school students, focusing on their use of specific details. Discussing the writing examples from Waltzer, Cox, and Heyman's study, we employ Aristotle's rhetorical theory to explore how clarity is achieved through specificity in writing. The analysis reveals both ChatGPT and students commonly omit detailed content, affecting clarity and argumentative strength, which affects how humans may detect AI-generated text. The paper suggests reinstating elements of classical rhetoric pedagogy in writing courses, particularly the style device of specificity. This will, we believe, not only improve student writing but also help educators to detect AI-generated text.

Introduction

Waltzer, Cox, and Heyman—in their study "Testing the Ability of Teachers and Students to Differentiate between Essays Generated by ChatGPT and High School Students"—discovered that students and teachers alike faced difficulty in determining whether essays were written by real students or by ChatGPT, especially student essays which were 'well-written' (2023). One of the writing prompts was the following: 'Why does literature matter?' This question is open-ended and subjective which gives students an opportunity to wrestle with and respond to a complex and qualitative idea. To answer such a question well requires originality of thought, some sophistication in understanding literature, and most importantly, specific statements that reveal a deep understanding of the topic. If the responses are based on platitudes or generalities, I am sure all educators would agree, then the answers fall short intellectually.

In their essay, Waltzer, Cox, and Heyman show us various passages; some written by ChatGPT and the others written by students. Although the goal of their study is to discover to what extent teachers and students could determine what was written by AI and what was written by a human, the most striking observation one gathers from the sample passages they provide is how *similarly faulty* are the written responses from both students and ChatGPT. As we reviewed the sample writings from their research, we immediately identified which samples were written by ChatGPT because the responses were, as expected, very generic, tightly

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organized, and grammatical--without the slightest hint of sounding colloquial or awkward. We also noted that the ChatGPT excerpts were void of those qualities in the prose that feel so human, such as complexity or burstiness (D'Agostino, 2023). Unfortunately, the student prose was equally generic, suggesting a lack of sophistication in absorbing the material or appreciating the genre. In other words, we analyzed parallel deficiencies in both ChatGPT and student writing, namely the generic responses.

If the student writing samples were quite similar to the writing samples of ChatGPT, then we can conclude that either the students are writing at least as well as a high powered AI text generator (which they are not) or that ChatGPT is unable to produce text beyond the level of a high school student (which it can). Because of its applicability to generate text in a multitude of fields and in various levels of sophistication and depth, we expect ChatGPT to surpass students. If it does not, then we need to know what is lacking in the features of its writing (or prompting)—not only to be able to increase our ability to detect ChatGPT but also to share this insight with students to improve their writing. The key element missing in both ChatGPT as well as the student writing is *specifics*. Specifics is one of the main principles of style in classical rhetorical theory which helps the writer achieve clarity. According to Aristotle in his *Art of Rhetoric,* "*…The virtue of style is to be clear…since if a speech does not indicate clearly it will not be performing its function (*2004, 3.2*).*

This fundamental principle underscores why classical rhetoric remains an effective pedagogical tool in improving student writing. The emphasis on clarity through specificity not only sharpens the discernment of AI-created content but also enhances the overall quality of student writing. By focusing on this key feature of clarity via specificity, this study aims to demonstrate how classical rhetoric can provide the necessary tools for both recognizing the limitations of AI while revealing concrete strategies for improving student writing.

Literature Review

Since its debut to the public in November 2022, ChatGPT has become a topic of great interest to educational researchers, professionals, freelancers, students, and teachers due to its applicability in perhaps every university course (Baig & Yadegaridehkordi, 2024). Because of its ease of use and incredible language and other text capabilities, ChatGPT is especially popular among students worldwide (Vargas-Murillo, de la Asuncion Pari-Bedoya, & de Jesús Guevara-Soto, 2023). ChatGPT as well is not only gaining popularity in numerous fields outside of education, but it is becoming a revolutionary aid in most professions. For example, in a study by Oh et al., ChatGPT was compared to a standard statistical model to predict the risk of death from sepsis for ICU patients in South Korea. Although ChatGPT was not as accurate as the statistical model, it was accurate in some cases and showed strong potential for accuracy in others (Oh et al., 2024). This is only one of many astonishing examples of how professional fields employ ChatGPT in a range of uses.

In the field of education, AI is undoubtedly playing a "burgeoning role" (Duran, 2024), and no teacher can ignore its presence. Research has shown that teachers across universities worldwide are embracing ChatGPT in nearly every discipline. As a writing tool, it is no wonder that it has been integrated into writing courses. For instance, Su, Lin, and Lai (2023) set up ChatGPT as a peer in courses on argumentative writing, while Bergström and Yvdal (2024) found that compared with peer feedback, ChatGPT's feedback was more detailed and constructive, especially when prompted to act as a 'thesis supervisor.' In other research focusing on ChatGPT's use in writing courses, ChatGPT served as an aid to generate different versions of an argumentative essay with mediocre results (Bádonyi, 2024). The use of ChatGPT in education can now be considered ubiquitous, as evidenced by the extensive research of Baig and Yadegaridehkordi (2024), who investigated 57 research articles that identified widespread use of ChatGPT, trends, and methods in higher education. It is certain that ChatGPT will be at the forefront of future discussions and research in education.

Despite the innovative if not extraordinary pedagogical uses for ChatGPT, there are also many grave limitations. Of the more alarming problems with ChatGPT, producing false data is at the top of the list. If it had intention, we could say it lies. Instead, experts refer to ChatGPT's production of inaccuracies as 'hallucinations' (Sakib, 2024). Working with inaccurate information is a significant problem in any discipline but could lead to great physical harm in the fields of science and medicine (Cong-Lem, Soyoof, & Tsering, 2024). In addition to generating false data, there are also concerns that ChatGPT reduces critical thinking because its users are relying on it too much (Murtiningsih, Sujito, & Soe, 2024). Other studies have noted similar ethical problems, noting that ChatGPT has a tendency to generate biased responses, a result of the human bias used to train the model (AlAli & Wardat, 2024). Numerous other systematic studies further confirm this wide range of serious problems with ChatGPT (Crompton & Burke, 2024; Baig & Yadegaridehkordi, 2024). These limitations are not trivial. No other technological pedagogical tool is so replete with these issues. Thus, Bhaskar, Misra, and Chopra (2024) ask the most urgent question of all in the title of their essay: "*Shall I use ChatGPT*?" In their study they found that when people perceive a higher risk when dealing with ChatGPT, they are less likely to believe it is useful or trust it, which in turn reduces their intention to use it.

But of all these issues, the inability for professionals in academia to detect the use of ChatGPT could be the most severe problem in education. Detection is key if one is to answer the questions, 'Are students completely misusing ChatGPT? Is ChatGPT writing the assignments for them?' Since much of the research shows that students tend to over-rely on ChatGPT (Durango, Blanco, Rodríguez, & de las Moras, 2024), remedies for detecting its use are critically important and urgent. Currently, one of the major ways to detect ChatGPT generated text is with AI detection software. Kar, Bansal, Modi, and Singh (2024) show that *Sapling* and other AI detection tools such as *Quillbot* are very effective in detecting AI-generated text. *Ghostbuster* is also effective. Tested across different types of writing, *Ghostbuster* has shown high accuracy and strong adaptability, making it more effective than other detection tools (Verma, Fleisig, Tomlin, & Klein, 2024). What

needs more research, however, is an explanation of what specific features the AI takes into account when evaluating text. Some research has identified that stylometric features are used in AI detection systems which trace aspects of language such as word frequency, sentence length, and vocabulary (Opara, 2024).

Although the majority of research focuses on how AI detects AI, there are a growing number of studies that emphasize the importance of using human intuition and experience to detect AI. Human detection may seem less effective since we cannot compute as fast and thoroughly as AI but humans have something AI does not have—thousands of years of using language and the production of billions of human-generated texts, all of which have come from the human heart and brain. Humans have the advantage to detect AI because we know what we sound like. We can respond authentically when a message feels wrong, biased, or uninspiring. To illustrate, a study by Fredrick, Craven, Brodtkorb, and Eleftheriou (2024) at a university in the Middle East shows that faculty members can successfully distinguish between AI-generated text and student-written content, with an average accuracy rate of 84%. Faculty relied on their expertise and intuition, using linguistic cues such as syntax and coherence to make these distinctions. In another study, Markowitz, Hancock, & Bailenson (2024) analyzed hotel reviews, and participants were able to detect human writing 80% of the time. AI hotel reviews were deemed more analytical and emotional but harder to read. AI struggled to express authentic human complaints. Another important study by Waltzer, Cox, and Heyman (2023) shows that while teachers were 70% accurate in their detection of AI, students were lower at 62%, highlighting the importance of experience. The authors did, however, find that a reviewer's confidence, experience with using ChatGPT, and subject expertise did not improve accuracy.

In our initial reading of the Waltzer, Cox, and Heyman study, we were intrigued regarding what the participants were seeing and not seeing from the samples. This led to the idea that perhaps our experience in classical rhetorical theory could shed some unique insights into the study. We believe this insight highlights concrete features that make human writing detectable over AI generated cause. There have been some studies trying to detect explicitly these features. However, the research seems more impressionistic than concrete as to the features of human writing. For example, Gunser, Gottschling, Brucker, Richter, Çakir, and Gerjets (2022) show that participants rated AI-generated texts as lower in stylistic quality, finding them less well-written, inspiring, fascinating, interesting, and aesthetic compared to human-written or original texts. This suggests that while AI can mimic human writing, it may lack the inherent qualities that make human writing more engaging and aesthetically pleasing—what has been called 'intrinsic dimensionality,' writing that is marked by higher complexity in sentence structures, description, and detail (Tulchinskii et al., 2023). For non-linguists, the items for analysis can get less exciting, focusing on differences in n-gram and bigram distributions, where human writing tends to be richer and more varied (André, Eriksen, Jakobsen, Mingolla, & Thomsen, 2023). Our study is unique in that it discusses the exact reasons why AI can be detected. As AI improves, deeper studies obviously will need to follow.

Methods

This research employs a rhetorical analysis and close textual reading of a feature in classical rhetorical theory, namely Aristotle's view of clarity. The analyses and close textual readings stem from three university professors each of whom have taught for over two decades. The study scrutinizes texts produced by ChatGPT and high school students from the article *Testing the Ability of Teachers and Students to Differentiate between Essays Generated by ChatGPT and High School Students* by Waltzer, Cox, and Heyman. The Waltzer, Cox, and Heyman sample consisted of 140 American high school students with an average age of 16.86 years, indicating that they were primarily in the 10th to 12th grades, or approximately 15 to 18 years old. These students completed writing assignments in their English classes, which were graded by teachers, resulting in a mean score of 85.95 out of 100, reflecting their academic performance as average to above average. The student demographic was predominantly white (57%) and native English speakers (96%), and the data collection took place early 2023.

By engaging with and building upon the findings of Waltzer, Cox, and Heyman, this research contributes to the necessary dialogue in the burgeoning field of AI in education, highlighting the importance of classical rhetoric in understanding and improving both AI and student writing. This dialogue is vital for all educators, as it shapes the future direction of teaching writing in an increasingly digital and AI-integrated world.

The rhetorical analysis is based on the Aristotelian concept that a key virtue of style is clarity. This analysis seeks to discern whether the writing by ChatGPT and students achieves this virtue. Clarity, in this context, extends beyond mere intelligibility or ease of readability; it encompasses the persuasiveness of the argument, the validity of evidence, and the specificity of the language. The textual analysis involves examining how specific or general the language in the given samples is and what the effects are when the specifics are lacking. This method determines whether the writing uses vague or general terms and whether it fails to provide concrete examples or detailed arguments to support its claims. The objective is to assess whether the writing, while possibly grammatically correct and easy to read (qualities indicated by measures like the Flesch readability index), actually impacts the reader in a rhetorical sense. The study operates under the premise that being specific is not just an ornamental feature of good writing, as suggested by Alsup (2005), but a fundamental element of one's argument.

In conclusion, the research method focuses on how well both ChatGPT-generated texts and student writings adhere to a key component of classical rhetoric, particularly the use of specific, clear, and persuasive language.

Results

If we examine the two samples provided in the Waltzer, Cox, and Heyman essay, we can see that both the AI version and the student version are lacking both

specific words and specific examples (5). First, we will examine the AI. The sentences are numbered.

> (1)Literature is considered important because it offers a means of examining the human experience and exploring various perspectives, cultures, and beliefs. (2) Through reading and studying literature, individuals are able to gain insight into the emotions, motivations, and experiences of others, as well as gain a deeper understanding of themselves. (3) Additionally, literature provides a way to preserve cultural heritage and pass on important values and traditions from one generation to the next. (4) Furthermore, literature can inspire, challenge, and entertain its readers making it a valuable form of art and expression.

This passage is clear in the sense that it is intelligible. But it is not clear in terms of information or argument.

We do not know what the AI means because there is nothing specific. "Literature" could refer to the plays or sonnets of Shakespeare, Martin Luther King Jr's essays, the letters of Charles Bukowski, or the songs of Bob Dylan. It could also refer to pamphlets at a dry cleaner or onion-skin-thin leaflets in a box of *Panadol* or *Strepsils* etc. We presume that literature means "fiction" as that is a key, functional definition (Todorov et al., 1973, 7). If the AI gave us just one example of an author— Shakespeare, Orwell, Laura Cereta, we could begin to understand its meaning. Or if it gave us one work—*Hamlet*, *1984, Letter to Sempronius Bilbous*, we could learn something specific from the passage. Specifics force us to learn the material; specifics invite us to interact cognitively with the message by 'showing' us the meaning, by appealing to our senses.

Exploring this further, we read that "Literature is a 'means… to examine and explore perspectives, cultures, and beliefs." But so too does music, painting, technology, food, dance, education, clothing, and even sexual conduct. The AI's claim about literature tells us nothing about the specific uniqueness of literature. It merely makes an unsubstantiated claim. The problem of course is that anyone (or should we also now say 'anything') can make an unsubstantiated claim. What students need to learn is that, to be taken seriously, their claims need evidence. Unsubstantiated claims are the tools of dictators, tyrants, and propagandists. 2+2=5 is a claim as is 2+2=4. Without evidence, however, claims are at best intellectually useless; at worst, dangerous. As educators race to deal with ChatGPT, it is urgent that we help students learn the tools of classical rhetoric to heighten not only their critical thinking but to equip them with the ability to compose substantiated claims that can be built upon, challenged, rejected, or praised in a democratic context, be that context in politics, education, or business etc.

In sentence two, AI claims that through literature we 'gain insight' into emotions, motivations, and the ability to deeply understand ourselves? For sure, literature offers this, but it is only a claim. How do readers know what the AI means by gaining insight? Would the insights gained from reading Howell's *The Damnation of Theron Ware* or Steinbeck's *Of Mice and Men* be different from

reading Sophocles' *Oedipus Rex* or Aristophanes' *Lysistrata* because the cultures are different?

What if our insight is dark and depressing? Should we read Fitzgerald's *Great Gatsby* to give up on the American dream? Should we read Mark Twain's *Letters from the Earth* to give up on both religion and the human race? If we reject the pessimism of Fitzgerald and Twain—all the while being entertained by them—do we then become more aware of ourselves? We do for sure, but we only can access the meaning of AI's general message if *we* do all the thinking, that is, if we provide all the specifics. The meaning of AI's claims can only become clear through specific language—which it does not offer.

The third sentence as well is crying out for specifics. ChatGPT has an opportunity to discuss how traditions are passed on through literature. A perfect example would be the Homeric epics. ChatGPT, if it knew the subject matter could even reference Eric Havelock's work *A Preface to Plato* which explains how the Homeric verses, the oral formulae, were a kind of technology which aided memory so that an oral society could pass on complex information (such as ship building) and important, moral precepts such as *being hospitable to strangers,* a precept illustrated in the story of the Cyclops Polyphemus who violates the Greek moral code of hospitality by capturing and eating his guests.

The fourth sentence too is a missed opportunity to be specific. How does literature inspire? Again, the foundational principle of style in classical rhetoric—specifics—would help to substantiate the claim. At the end of Steinbeck's novel the *Grapes of Wrath*, for example, Rose of Sharon offers her lactating breast to feed a starving man. This scene inspires us to cheer for the dignity of all human beings regardless of social norms or taboos. Or, as ChatGPT blandly put it, literature challenges us. Again, the claim is true, but only if it is supported by something specific. For example, after he kills a pawnbroker and her sister, should we cheer for Raskolnikov in *Crime and Punishment* to escape the police? Does literature also challenge us to read on if the author's prose style is beautiful yet the topic revolting? If so, ChatGPT could argue that what makes Nabakov's *Lolita* such a masterpiece is that it both challenges and entertains us; challenges us, because the subject of the novel is an illegal love affair between Humbert Humbert, a man about 40 years old, and Lolita, a 12-year old girl; entertains us, because the prose style is exquisite:

> "*Lolita, light of my life, fire of my loins. My sin, my soul. Lo-lee-ta: the tip of the tongue taking a trip of three steps down the palate to tap, at three, on the teeth*."

We can conclude that one way to detect AI generated prose is that it is fraught with platitudes and generalities—organized fairly well and grammatical. If you want ChatGPT to be specific, you must continually revise your prompts and goad it for more. Basically, if ChatGPT had produced some of the points we made in our analysis above, would it have been harder to detect because it seems more authentic, or would it have been easier to detect because it referenced numerous works?

Student writing, unfortunately, often offers the same platitudes and generalities as ChatGPT, only without good organization or good grammar.

We now turn our analysis to the student sample:

> (1)Literature matters because it shapes people's minds. (2) Growing up with a good understanding of different pieces of literature can build intelligence and prepare people for adulthood. (3) Literature can expand creativity, help with speaking in conversation, and just overall enlighten the human brain on different ideas in the world. (4) Even going into adulthood, it is still important to experience the joy of reading and overall is a key part to a person's ability to be successful in life.

Just as ChatGPT presents general, unsubstantiated claims, so too does the student. The claim "Literature… shapes people's minds" could also apply to any number of school subjects, religious faiths, hobbies, familial relationships etc. Math and biology shape people's minds. Attending church could shape your mind, and so could practicing *jeet kun do*, or obeying your mother or father. Interestingly, the student has made a remarkable point. If literature can shape a mind, then literature can be a rival influence to parental, governmental, or societal conditioning. Literature can therefore be dangerous, subversive, radical. But the general style does not alert the reader to the student's brilliant idea. Thus, in the hands of a tyrant, extremist, or ignoramus, literature can be censored, banned, burned. *Harry Potter*, for showcasing witchcraft; the *Tales of Peter Rabbit*, for only portraying middle-class rabbits; *Huckleberry Finn* because Huck did not wash before church and of course because of the racist wording; Luther's translation of the Bible because it was written in common language, a translation accessible by both the priesthood and the penniless. "Literature matters," the claim is both a reason to read and to celebrate if you are democratic and free-minded, a lover of rights; or it is a reason to confiscate and destroy if you are fascistic, tyrannical, hungry to control the thoughts and behaviors of others. But none of these ideas come through because the style is general; the student has claims but no evidence. If the elements of classical rhetoric would be used, the student writing would be better because it would be clearer, more persuasive, more entertaining.

In sentence two, the student claims that literature can make you smarter and more mature. This sounds like a claim the student believes a teacher wants to hear. It would be clever for the student to explain exactly how literature prepares you for adulthood. The idea seems a bit sweeping as the majority of adults the world over are not well-read in literature. It is easier to see how math or science or computers prepare one for adulthood in terms of a career, but to say that literature prepares one for adulthood is more vague, more inexact. I suppose the student could argue that the study of literature helps with soft skills such as empathy or emotional intelligence, but it all depends on the literature. The masterpieces in Mortimer Adler's Great Books series have the goal of teaching morality and ethics. Take the Greek dramas, for example. They showcase moral conundrums and force us to think critically on gray areas of morality. Orestes must avenge his father's murderer if he (Orestes) is to be a worthy son, but what if the murderer is

Clytemnestra, his own mother? Now what should Orestes do? Oedipus faces a similar moral dilemma. In his confusion, he murders his father and marries his own mother. From Greek literature, we also learn that if we offend the gods, we get thrown off course like Odysseus, wandering in exile for ten years, fighting to return home. We also learn that no matter how far we venture in life, the ultimate goal is returning home, older, wiser, happier. Is not that the same message as Dorothy's in the *Wizard of Oz*? *There's no place like home*. But is this what the student means? We can never know unless the student is specific, unless the student applies the style devices of classical rhetoric. Generalities tell us nothing; they are unclear.

The student's third sentence has too many broad ideas, each worthy of their own focused paragraph. Literature could expand creativity, but how? The Greek and Roman rhetorical schools would have agreed with the student, but they would have shown students a concrete pedagogical tool to bring about that creativity called *imitatio,* or imitation. In the ancient world, students would copy and imitate passages of Homer or Cicero, trying to create similar passages by writing in the same style, using the same tropes and schemes, but writing about their own subject matter. Regardless of the many possible ways literature can enlighten our minds or foster our skills, we need to know exactly how one achieves that skill. Otherwise, it is just an empty claim and can be easily refuted by claiming the opposite: Literature does not matter; literature does not prepare us for adulthood; literature does not enlighten us; or literature does not make us creative. In fact, the data shows that these negative claims about literature might be true, we cringe to say, because we appreciate literature. But in reality, at least outside the university walls, romance/erotic novels matter the most if one judges by sales, then books on crime, religion, science fiction, and horror. Today, more people know who Freddy Kreuger is than Nick Barnes. Literature is nowhere on the list of top sales. *Naked Lunch* is a restaurant in Cap d'Adge, correct? No. It is a novel by William S. Burroughs. Thus, because literature is not popular, both ChatGPT and students need to give us more than a claim regarding how literature prepares us for adulthood.

So, what do we learn in analyzing these passages through the lens of classical rhetoric?

We learn that both ChatGPT and students need to support claims with specifics.

We learn that if either ChatGPT or the student had specifically referenced any piece of literature, any character, any scene, the writing would become clearer, claims enriched with evidence, the writer's voice singing with personality. Without the specifics, the passages are general and ineffective, void of substance, boring and flat, saying nothing.

Conclusions

This study, through a detailed rhetorical analysis of texts generated by ChatGPT and high school students from Waltzer, Cox, and Heyman's study,

underscores a significant gap in both the writing generated by AI as well as students. Both lack the classical rhetoric device of specificity. We show that the absence of specificity leads to a deficiency in clarity. This discussion is critical in understanding the limitations of AI-generated text as well as revealing the opportunity to improve student writing by incorporating elements of classical rhetoric into the lesson plans. Our analysis demonstrates that specificity, a foundational principle of classical rhetoric, is not merely an aesthetic choice but an important element of effective communication. Both ChatGPT and student writing, while varying in grammatical correctness and organization, consistently fall short in providing specific, detailed arguments and examples that are essential for clear and persuasive writing. This issue becomes more pronounced in educational institutions where students are increasingly tempted to use AI technologies like ChatGPT.

Therefore, the study advocates for a renewed focus on classical rhetoric in writing instruction, emphasizing the need for explicit teaching of specificity as a means to achieve clarity. By doing so, writing teachers can equip students with the necessary tools to not only improve their writing but also critically evaluate and understand AI-generated content. As ChatGPT and similar technologies become more ubiquitous, the role of classical rhetorical principles, particularly in cultivating a specific and clear writing style, becomes increasingly vital. This research contributes to a growing dialogue in the field, highlighting the relevance of classical rhetoric in an AI-integrated educational environment and its importance in preparing students for the challenges of the digital age.

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Promoting Teachers' and Students' Metacognitive Skills: Developing an Intervention Program

*By Eleonora Papaleontiou-Louca**

Pro-Me-ToM (Promoting Metacognitive and Theory-of-Mind Skills) is an Erasmus+ collaborative project funded by IDEP (Foundation of European Programs for Lifelong Learning) and has been conducted by researchers from five countries (i.e., Cyprus, Greece, Hungary, Portugal, and Romania), aiming to both investigating and to promoting teachers' and students' metacognitive skills. Within this project a well-designed educational intervention has been developed, translated and applied in five countries. Specifically, this research project aimed to enhance such skills as metacognitive skills, epistemic beliefs and theory-of-mind skills of both teachers and students. These critical skills are examples of students' higher-order thinking, and are expected not only to help students to "learn how to learn" throughout their lives, but also to enable them to interpret human behavior in order to coexist functionally with others. This paper describes a specific educational intervention program implemented through "Action Research". The training program consisted of 12 (2-hrs) sessions, it has been implemented in the five participating countries, and all participating teachers and their students were administered a pre- and post-test (still being analyzed). This paper focuses and presents the pillars of the training program as well as examples of the intervention program content and tools.

Keywords: metacognition, theory-of-mind, epistemic beliefs, teachers' training program, intervention

Introduction

The great interest in metacognition stems from the widespread belief that students ought to be lifelong learners, equipped with the skills necessary both to solve problems in school and to extrapolate these skills into life through understanding their own thinking, learning, and strategic approaches to problem solving (Papaleontiou-Louca, 2014, p.7).

> Therefore, …one of the main goals of education is to make the students gain the thinking skills and strategies which they will use throughout their lives, rather than storing information. A good education should be able to show the students how to learn, how to remember, how to motivate themselves and how to control their own learning, so that they can teach themselves how to learn (Aydin 2011, p. 274).

Teachers' training programs usually aim in enhancing teachers' competency in various dimensions, such as induction, content, pedagogy, organization and assessment. Research findings reveal that training programs implementing and promoting metacognitive strategies lead teachers in a continuous improvement in

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all dimensions of teaching competency, by internalizing metacognitive skills and implementing them through self-regulation. Especially, planning, monitoring and evaluating are three basic strategies in metacognitive interventions that help teachers to become more confident by enhancing their teaching competencies in practice. There is an urgent need to increase the efforts towards implementing more Metacognitive interventions, and therefore enhancing teaching competency and help students to learn how to learn (Fathima et al., 2014).

Other studies (e.g., Artzt & Armour-Thomas, 1998; 1999) suggest that the metacognition of teachers and their ability to reflect on their instructional practice and underlying cognitions in a comprehensive manner, play a well-defined role in classroom practice and in students' ability to learn how to learn, so perhaps where we should focus on first, is on teachers' metacognitive training.

Similarly, Rahman et al. (2010) found that student of more metacognitively aware teachers performed better on metacognitive tests. Metacognitively aware teachers could be, for example those who tended to think more about what they were doing in classroom. This is consistent with other research findings that suggest that thinking about thinking and about learning is promoting a deeper and more permanent learning, therefore, such training programs are more than recommended both for teachers and students.

Theoretical Framework

Metacognition has attracted plenty of scholarly attention basically because it is essential for students as well as adults to learn how to learn. Although the term 'metacognition' has become fashionable referring to a hot research area, the definition of the term is a complex task.

The concept of "metacognition" was initially proposed by Flavell (1976, p. 232) who described it as "knowledge and cognitive about cognitive phenomenon", and "individual's knowledge about his/her own cognitive process, and employing this knowledge to inspect cognitive processes". Based on Flavell (1979), metacognition is the individual's awareness of how a person learns and what s/he does, to gain proper knowledge and succeed in one's own cognitive aims; the ability to adopt cognitive skills necessary for passing a test, knowledge of which strategies are best for a specific task/goal, and the assessment of one's own cognitive processes before, during and after a task. Finally, metacognition is a cognitive activity or knowledge that has to do with cognitive functions (Flavell, 1993).

Traditionally, metacognition is described as thinking about thinking or the monitoring and regulation of thinking. Initially, Flavell (2000) referred to metacognition as "knowledge that takes as its object, or that regulates, any aspect of any cognitive endeavor" (p. 16). Since then, the term 'metacognition' has included the awareness and control of one's own mental activities, planning, monitoring, and evaluation (Aydin, 2011).

Moreover, the definition of metacognition has been broadened in that it now includes not only "thoughts about thoughts" and cognitive states (as it was initially described) but also affective states, motives, intentions, and all those states related

to cognitive phenomena, as well as the ability to consciously and deliberately monitor and regulate them (Papaleontiou-Louca, 2008).

Human beings (Shea et al. 2014) and empirical evidence has indicated that human metacognition is dependent on the activity of the prefrontal cortex (Fleming et al., 2010; Morales et al., 2018; Shekhar & Rahnev, 2018; Zheng et al., 2021) and can guide learning (Guggenmos et al., 2016). A recent paper demonstrated that humans have the capacity to perform repeated hierarchical evaluations of their judgments up to at least fourth-order judgments (Recht et al., 2022). This finding was recently replicated by a different group of researchers (Sherman and Seth, 2023).

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Moreover, metacognition is considered an evolutionary advantage for humans (Shea et al., 2014), which depends on prefrontal cortex activity (Fleming et al., 2010; Morales et al., 2018; Shekhar and Rahnev, 2018; Zheng et al., 2021), and which is empirically shown to guide learning (Guggenmos et al., 2016). A recent paper demonstrated that humans have the ability to repeatedly make hierarchical evaluations of judgments up to at least the fourth order (Recht et al., 2022). This finding was recently replicated by another group of researchers (Sherman and Seth, 2023).

Although metacognition may have rather vague boundaries, key distinctions can be made that help clarify the literature:

First, there is the well-known distinction between metacognitive knowledge (knowing about what you know) and metacognitive skills (knowing how to regulate what you know). Else, we can distinguish between knowledge and skills - between "knowing that" and "knowing how," the old distinction between theory and practice, and between competence and performance (Papaleontiou-Louca, 2014). Knowledge about cognition refers to the information that thinkers have about their own cognitive processes. Regulation of cognition refers to the activities used to regulate and oversee learning. These processes include planning activities (predicting outcomes, scheduling strategies and various forms of vicarious trial and error, etc.) prior to undertaking a problem; monitoring activities (monitoring, testing, revising, and re-scheduling one's strategies for learning) during learning; and checking outcomes (evaluating the outcome of any strategic actions against criteria of efficiency and effectiveness) at the end (Brown et al., in Flavell and Markman, 1983).

'Metacognition' has been also distinguished in *knowledge about cognition* and *regulation about cognition* (Brown, 1987): Knowledge about cognition can be information that human thinkers have about their own cognitive processes, while 'regulation' refers to activities used to regulate learning and its affected aspects (e.g., anxiety, fear, interest, self-esteem, self-efficacy).

Similarly, Kluwe (1982, p. 202) distinguishes metacognition in (a) the thinking subject has some knowledge about his own thinking and that of other persons; (b) the thinking subject may monitor and regulate the course of his own thinking, i.e., may act as the causal agent of his own thinking.

Examples of monitoring includes questions such as "How much effort do I have to put into learning this material?"; "Did I sufficiently learn this material to remember the details later on?"; and "How sure am I that this answer is correct?" (Roebers, 2017, p. 23).

The efficacy of such educational interventions for both teachers and students are of the utmost importance, therefore it is imperative that such programs prove durable and generative as they pertain to student outcomes (Nation et al., 2003). This is also true for teachers' training programs, which are often relegated. As such, any teachers' training programs seem to maximize the classroom's investment.

As research findings show, the ability to effectively manage one's learning seems to lead to success in and beyond school and accuracy in self-evaluation (which is a metacognitive skill) was found to be related to school performance in adolescence (Demetriou & Kazi, 2001, p. 525).

Brown et al. (1983) continue to emphasize the important implications of metacognitive development in education by stating that "Regarding the implications for education, confounded treatments that work are extremely interesting in themselves. Clarification of the specific factors responsible for positive effects may allow refinements of the package, but an intervention that works (for any of a number of reasons) is a desirable outcome in its own right".

The Aim of this Paper

This paper aims to shed light on significant aspects of teachers' education, which are often overlooked. These include training and teaching to train metacognitive and theory-of-mind skills and epistemic values.

The novelty is that the developed educational program lies on three well-presented pillars and involves both teachers and students.

The paper's contribution is not only to theory but to practical implementation as well, with a detailed description of the training method "action research".

The Project: Aims and Design

Based on successful evidence-based practices reported in the literature, we designed a detailed educational training program aiming at supporting teachers' metacognitive development and enable them to promote their students' metacognitive skills, through specific teaching practices (Papaleontiou - Louca, 2023).

The intervention described in this paper is part of an Erasmus+ funded project, titled "Promoting the Development of Teachers' and Students' Metacognitive and Theory-of-Mind Skills" currently being implemented in parallel in five participating countries. These teachers' training programs are being conducted virtually to encourage the participation of teachers in remote areas who have limited opportunities to participate in professional development programs.

Prior to the training, teachers and students have been administered pre-tests (specifically designed for this project), and after the training, all participants

completed a similar post-test. Both pre- and post-tests, as well as the content of the training program, and the materials used, have all been translated into the languages of the five participating countries.

Each teacher training intervention program consisted of 12 (120-minute) online sessions was designed for primary and secondary-level- teachers in the five participating countries: Cyprus, Greece, Hungary, Portugal, and Romania.

While the results are still being analyzed, the main focus of this paper is to present the content and philosophy of the intervention and to suggest similar promising interventions in other countries and educational systems.

The basic goal of this research project is to promote teachers' and students' awareness and development of metacognitive skills, both at primary and secondary educational levels (Papaleontiou-Louca, 2023).

More specifically, the Pro-Me-ToM project aimed to provide a well-designed and tested educational program for the development of teachers' self-awareness, self-monitoring, and self-evaluation, as well as to promote students' metacognitive skills, epistemological beliefs, and theory of mind (ToM) skills, which can be considered as crucial skills for a meaningful participation in the information society (Papaleontiou-Louca, 2008).

Specific activities and materials had been included in the training program, such as discussions on effective practices based on cutting-edge research in the field, case-studies that promote metacognitive awareness in various domains, etc. (Papaleontiou-Louca, 2023).

Before and after each (country's) training program, pre- and post-tests had been delivered among participants, so as for metacognitive awareness and skills to be assessed and finally the effectiveness of the intervention program to be defined.

Rationale and Description of the Intervention

To better understand the logic of this intervention program, participant teachers were first informed about previous educational interventions on ‘metacognition’. While many interventions aimed at developing metacognitive knowledge, strategies, and skills in various knowledge domains applied in school settings, it does not appear in literature such a complex intervention, involving both teachers and students (at the primary and secondary level) which simultaneously promotes metacognitive, epistemic, and ToM skills (Papaleontiou-Louca, 2023).

Participant teachers have initially been informed about the results and evidence of previous educational interventions on ‘Metacognition’ in order to better understand the logic of the present intervention program. Though many interventions have been applied in school settings aimed at fostering metacognitive knowledge, strategies, and skills in various knowledge domains, the literature does not seem to refer to an Intervention of this complexity, involving both teachers and students (of both elementary and secondary educational levels) and promoting simultaneously metacognitive, epistemic and ToM skills (Papaleontiou-Louca, 2023).

Besides, the program aimed in supporting teachers and students to transfer their self-regulating metacognitive knowledge and skills to new tasks and contexts.

All these aims and benefits have been pursued through the development and implementation of 'Action research' where teachers' acted as researchers in their own classrooms and with the final aim being to explore the actual results of teachers and students' metacognitive development through pre-tests, post-tests and follow-up tests few months later.

During the intervention period, we have tried sharing broadly the project's objectives, processes and results through an interactive online platform aiming at both providing continuous support of students and teachers' participating in the project and advising teachers who want to implement it in their schools or countries.

The next step after the intervention and the completion of the program, is to disseminate the content, activities and results both nationally and internationally so as to multiply the target group in more schools and countries, through a specifically developed web- page, conferences and publications (Papaleontiou-Louca, 2023).

The Methodology Used: Action Research

The Methodology used in this particular training program was based on the philosophy of 'Action Research', where teachers asked to be acting as researchers in their own classes, they plan, teach, evaluate, reflect and re-act based on reflection and feedback received.

"Action Research" is defined as a participatory, inductive procedure of teacher professional development, and its development cycle (planning, teaching, evaluation-reflection, re-planning, re-action) is described. Useful tools such as reflective diaries, observations, evaluative reflection, feedback, and re-action are discussed and an inductive analysis of diaries based on grounded theory (Glaser & Strauss, 1967) is promoted (Papaleontiou-Louca, 2023).

Additionally, the project plans to analyze the teachers' diaries including comparative analysis, coding, categories of change, as well as the teachers' role as mentors/critical friends (Koutselini, 2020; Papaleontiou-Louca, 2023).

So, about four out of the twelve on-line sessions of the *Pro-Me-ToM Teachers' Training Program* where devoted in discussions and feedback between teachers' trainees and educators, who shared their thoughts, plans, activities, concerns, difficulties and/or possible satisfaction of both themselves and their students and asked for more assistance and guidance to continue their educational trials on metacognition.

The Three Basic Pillars of the Content of the Intervention

The content of our *'Pro-Me-ToM' Teachers' Training Program* has been designed by five academics and was built on three main pillars:

a. Metacognitive Skills (in general)
b. Epistemic beliefs and
c. Theory of Mind skills, which we analyze below in more details:

1st Pillar -The Concept and Value of Metacognition

After a brief introduction to the concept of metacognition, its importance in educational settings was analyzed and discussed. Metacognition has been defined as "cognition about cognition" and a secondary meta-representational process. We also referred to three aspects of metacognition: metacognitive knowledge, metacognitive experience, and metacognitive control and their subcategories: namely, metacognitive knowledge (as either declarative, procedural, or conditional), metacognitive experience [including feelings and judgments about cognitive tasks (Efklides, 2008; Efklides et al., 2018)] and metacognitive control as a way of coordinating cognition, including metacognitive strategies of the learning process (e.g., planning, monitoring, controlling, and evaluating).

Having presented and analyzed the concept and importance of metacognition, the emphasis shifted to teaching and learning, and practical ways to teach metacognitive skills in the classroom were discussed. In this way, an effort was made to familiarize teachers with different metacognitive strategies and ways to teach them in order to promote students' metacognitive skills. These methods included direct instruction, indirect experience, and elicitation through practice (e.g., collaborative learning projects).

More specifically, two basic methods of teaching metacognition were presented:

a. explicitly teach what metacognition is and how it is important to develop students' minds; students explain the benefits and examples of leading their own minds

and

b. implicitly, becoming a model for students' thinking, by using a variety of metacognitive techniques
(Papaleontiou-Louca, 2023)

To make the program more practical, we encouraged teachers to discuss how they could help students build a knowledge base with all three types of metacognitive knowledge (declarative, procedural, and conditional), and to give students tasks to practice and apply new strategies as well as to receive useful feedback regarding their learning and effectiveness.

The current program also discusses ways on how teachers can implement metacognitive strategies on a daily basis. More specifically, the intervention program focuses on raising teachers' awareness of the importance of metacognitive control processes (planning, monitoring, evaluation, etc.) (Papaleontiou-Louca, 2023).

2nd Pillar - Epistemic Beliefs

The second pillar of this intervention is focused on 'Epistemological Beliefs'. This pillar discusses how students' epistemological beliefs are related to their

academic performance and various cognitive tasks (e.g., comprehending multiple texts and engaging in critical thinking).

Special emphasis was placed on how epistemological beliefs develop. The developmental task underlying the achievement of mature epistemic understanding appears to be the reconciliation of the subjective and objective dimensions of knowing (Hofer & Pintrich, 1997; Kuhn et al., 2000; Iordanou, 2016). Initially, the objective dimension dominates and subjectivity is excluded. It is also noted how people's epistemological beliefs influence their motivation to engage in critical thinking and, ultimately, their learning and decision-making processes. According to Kuhn et al. (2000, pp. 2-3) in (Papaleontiou-Louca, 2023):

> "Someone at the absolutist level sees knowledge as an objective entity, as located in the external world. … the multiplist relocates the source of knowledge from the known object to the knowing subject, hence becoming aware of the uncertain, subjective nature of knowing. … The evaluativist reintegrates the objective dimension of knowing, by acknowledging uncertainty without forsaking evaluation. Thus, two people can both have legitimate positions - can both "be right" - but one position can have more merit than the other" (Papaleontiou-Louca, 2023).

3rd Pillar - Theory-of-Mind Skills

The third fundamental pillar of this intervention refers to the development and promotion of students' ToM skills.

As such, the discussion focused on the following questions related to the concept and development of "theory of mind": e.g., "What is theory of mind?"; "Why is theory of mind important?"; "How does theory of mind develop from infancy to mid-childhood?"; "Can theory of mind be taught or improved?" etc. (Papaleontiou-Louca, 2023).

Teachers were introduced to the meaning and definition of ToM and its importance in social interaction and communication was discussed. Its importance was also discussed in terms of the impact of ToM deficits on different areas of functioning. Teachers were also familiarized with challenges and research findings showing that ToM emerges early in life, while advanced ToM skills emerge in middle age. Finally, findings from intervention programs were presented, focusing on interventions aimed at promoting ToM skills in early childhood. Examples of activities were provided and stories/scenarios were presented that could be used to teach children ages 10-11 to improve their ToM skills (Misailidi et al., 2013).

Since the whole intervention cannot be presented in details within the scope of a single article, more information about it can be provided upon request to the authors of this program (Papaleontiou-Louca, 2023).

Practical Applications

In combination to the theoretical part of the program, much emphasis has also been given in developing practical activities, asking teachers to suggest ways to engage students in hypothetical scenarios, encourage students to think about - and

discuss - an actor's thoughts, feelings, or future actions and behavior. More importantly, we asked teachers to refer to real classroom examples, suggesting at least one educational activity to promote metacognitive skills, and share their ideas with their colleagues.

Some specific examples of practical applications based on the three pillars include:

1st Pillar -The Concept and Value of Metacognition

Metacognitive activities and techniques include reviewing reading passages to make sure they understand them, monitoring their own minds to check that they are moving optimally to achieve their goals, thinking aloud, writing summaries, making 'mistakes' deliberately, evaluating one's own reading comprehension, etc.).

For example, we asked 'How comprehensible (easy to understand) does the story you just read seem to you? (circle a number)

1. Not at all understandable
2. A little
3. Quite a bit
4. Very understandable

2nd Pillar - Epistemic Beliefs

Examples include a*sking students questions such as:*

"What do you do when you talk to a friend about a topic and argue about who is right?"
How often do you research to find out how expert someone is on a subject to decide whether to trust what she/he say?

3rd Pillar - Theory-of-Mind Skills

An Example of 'Theory-of-Mind' Activity is the 'Reading the Mind in the Eyes' Test

Below there are pictures of people's eyes. Each picture has four words under it. I want you to look carefully at the picture and then indicate the word that best describes what the person in the picture is thinking or feeling.

Look at this person. Do you think he is feeling jealous, scared, relaxed or hate?

An example of Teachers' Theory of Mind questions on related Practices is referred below:

Below is a list of statements about the ways you talk to your students about their own minds and emotions and those of others. Please read each statement carefully and rate how strongly you "agree" or "disagree" by selecting the appropriate option on the right of each statement.

Definitely disagree/Slightly disagree/Slightly agree/Definitely agree

- I talk with my students about the distinction between different mental activities (e.g., remembering, imagining, having dreaming, desiring, deciding, foreseeing and thinking)
- I encourage my students to name and distinguish their own emotions
- I explain to my students that in order to understand someone's behavior, it is important to know her/his mental states (e.g., thoughts, wishes, etc.)
- I ask my students to find in their school textbooks words describing the mind (e.g., want, believe, aim to, know) and think about their meaning
- I engage in discussions with my students about the way lies can mislead other people
- I frequently use questions/questioning to trigger my students see things from other people's point of view

Deliverables

It is expected that the analysis and discussion of the results (in progress) of this project, along with the basic conclusions and related proposals, will lead to at least 2-3 scholarly (Scopus) articles to be submitted to international peer-reviewed journals and some presentations will disseminate our results at international conferences.

Additionally, a Toolkit/Guide booklet for teachers is being prepared as a helping guide for developing students' metacognitive skills (in all partners' languages) (Papaleontiou-Louca, 2023).

Among other deliverables of this project, teachers have been asked to prepare a 'Reflection Diary' where they express their thoughts, feelings and reactions by both students and themselves, related to the program, as well as comments which will go under a qualitative analysis and results will be published.

Some preliminary results, though, mainly from teachers' reflective diaries can be presented below indicating that the program seemed to has succeeded its basic aim in promoting teachers' and students' thinking and metacognitive skills.

Preliminary Results

Preliminary -Qualitative results have been drawn based on the Teachers' Reflective diaries, a sample of which are presented below:

- *"The students began to reflect and think critically for each scenario they were given. They became more observant and paid more attention to things that they previously considered as unnecessary details. There was also a change in their attitudes and in their relationships with each other. They were puzzled and put themselves in the other person's shoes to think about the reasons that made them act the way they did. At the same time, they were able to express their feelings, to justify their actions and in terms of learning, they felt more able to express the way they thought to arrive at an outcome. The difference was evident compared to the original questionnaire. To a large extent, students applied metacognitive skills cultivated during the year" (N. E. & Y. P.).*
- *The program gave me the opportunity to reflect on my teaching and to see that many of the activities I used in my lessons involved metacognitive skills and were in line with the Theory of Mind. It also gave me the opportunity to enrich my quiver with new ideas for developing metacognitive skills. In addition, with the start of the training, I went through the process of thinking about and incorporating metacognitive skill development activities into my lessons more systematically (D.P.).*
- *I do not believe it! I feel satisfied! I learned and I am implementing many new things that seem to work well!*
- *I feel very happy and the same my students. …. One of my students said at the end of the lesson: this is the reward! Finally, many teachers asked that the program is repeated and one of the colleagues said characteristically:*
- *"I thank you very much for the valuable knowledge I gained! It was really one of the most useful seminars I attended! (S.D.)".*

Teachers views, as shown above and as they are revealed from their diaries seem quite positive, both for themselves and for their students. By the end of the project teachers felt more confident how to work and how to promote metacognitive skills, epistemic beliefs and theory-of-mind skills to their students. Some of the activities developed in the program were familiar to them, though not all of them realized that what they were doing was quite 'metacognitive' in nature. What seems to be a consensus in their reflections, though, was that they can now apply more systematically and more consciously and purposefully the various types of metacognitive thinking in their teaching.

From a qualitative point of view the above indications so far seem to suggest that such programs will be promising in the enhancement of our educational system and people's thinking skills. Such educational programs seem to benefit both the educators and the students and to promote higher types of thinking and learning skills. That's why we suggest that training programs on the promotion of metacognition need to be included both in teachers' basic studies at the University as well as in their professional development in the process of their educational career.

As per our quantitative analysis, we planned to do a lot of statistical testing and we have already started some exploratory testing on the tools which seem to give good results.

More specifically, we started with validation and reliability of our tools/ measures, which were established through pilot-testing in all participating countries, and then we finalized our coding schemes.

We then contacted Standardization/Reliability of the final tests (Cronbach's alpha).

Our Post-tests to students and teachers included self-assessments/ measurements (via qualitative measurements, observations, focus group interviews, diaries, etc.) and there has been a follow-up-test to students of both educational levels, to assess the educators' training impact on the formers' skills

Our Data Analysis included a. Quantitative Analysis (comparison of pre- and post-test and quantitative separately) of b. Follow-up assessments' analysis in each country's students, and c. Qualitative Data Analysis of Teachers' Assessments.

We then proceed with confirmation, induction per time point and induction between time points.

Our statistical data so far are going to be presented soon in an educational Conference.

Discussion and Conclusions

Though the Training Program has been just completed and the results need yet to be analysed, it might be noted that the interest by the side of teachers is great as well as it is their willingness to participate and apply the program in their classrooms.

The detailed design of the training program by five professors, who can be considered experts in the field (with many years of experience and many publications in the area), gave it a strong scientific basis and succeeded in gaining the educators' trust.

Teachers have shown much reflection and they made remarkable efforts to shift from traditional teaching and emphasis on memorization towards a more reflective way of teaching.

Their enthusiasm helped them to become creative enough in inventing new ways of teaching promoting higher thinking skills, critical and reflective thinking and therefore students' deeper learning.

As teachers shared with us during our on-line sessions, students found much more interesting the topics that engaged them in a more thoughtful and reflective way of acting and demanded deeper thinking than activities used to take place in traditional lessons.

Of course, time is needed for these metacognitive skills to be acquired and effectively used in various school subjects. Similarly, appropriate training is required to be offered, not only for teachers but also for students. Such educational programs should ideally begin at a very young age and fully blossom in primary and secondary education (Metallidou & Moraitou, 2021).

Especially in our rapidly changing world, programs such as the Pro-Me-ToM project, seem to consist a necessity, if we really aim to create thinking and reflective people and promote students' thinking skills and develop active learners through life.

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Flipping a Language Subject to Teach English Grammar and Oral Skills at Tertiary Education

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University education must respond to social demands and adapt to the needs of students in the teaching-learning process. This article reports on a study that focuses on how a teaching proposal based on the flipped classroom has an impact on grammar learning and on the development of oral skills at tertiary education. The main objectives of this article are the following: 1. To observe how flipping a grammar and a speaking class allow students to acquire grammar content, improve their speaking skills and develop social competences and 2. To know students' opinions about the methodology used in the teaching-learning process. The study uses a mixed-methods research design (qualitative and quantitative) by observing the students' performances in grammar learning and oral presentation and by using a questionnaire at the end of the semester. The results of the questionnaire indicate that most students were satisfied with the proposed methodology and are aware of its benefits in their learning process.

Keywords: flipped classroom, grammar teaching, oral skills, *Kahoot*, social competences, active methodologies.

Introduction

Innovation, technological development and the teaching of English as a foreign language have been the focus of debate among academics and language specialists in the last decade. This has been due to the need to update English teaching in order to motivate students and adapt teaching to the demands of the new times (Gabarrón Pérez et al., 2020; Martínez Navarro, 2017).

The development of active learning strategies is relevant to making students direct their own learning. Consequently, students are given a central role so that they can improve their performance and understanding in the classroom (Arjomandi et al., 2018; Lumpkin et al., 2015). Therefore, it is important to explore methods that engage students in the teaching-learning process. In this sense, the choice of methods of active learning improves students' learning and the acquisition of competences (Khan et al., 2017; Vygotsky, 1978).

The flipped classroom is an innovative learning model that has been used in language learning mainly in the past decade (Bergmann & Sams, 2012, 2014; Marshall & Kostka, 2020; Talbert, 2017). The Flipped Learning Network defines flipped learning as "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment

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where the educator guides students as they apply concepts and engage creatively in the subject matter" (Flipped Learning Network, 2014a, p. 1).

This model is useful for students to work on individual and group activities outside the classroom. Activities based on the flipped classroom methodology were chosen due to the uncertain situation caused by the pandemic when the academic year 2021–2022 started. Although all the students were in the classroom at the beginning of the semester, the possibility of having new waves of COVID-19 made the teacher frame the teaching-learning process in a model that promoted autonomous learning. In addition, the fact that the students registered in the subject had received dual instruction in the previous academic years (2019–2020 and 2020–2021) meant they had autonomy in the teaching-learning process. In fact, having received dual instruction could be taken as a positive aspect that would benefit students in accomplishing the activities framed in the flipped methodology presented in this article.

This study is justified because framing the teaching-learning process in the methodology proposed by the flipped classroom to teach grammar and oral skills means that students can learn in a more autonomous way at tertiary education. This is due to the fact that they can organise their time in the individual learning space. Moreover, group space becomes more dynamic and interactive because students are able to apply what they have already learned. This way of teaching favours the acquisition of some social competences such as leadership and communication. Thus, the different activities used in an advanced English class in higher education (see section 4) would not only contribute to the acquisition of the content and skills of the subject but also to the enhancement of social competences that will be useful for the subject and for other aspects of students' lives.

Bisquerra and Pérez (2007) define these competences in the following way: "[…] la capacidad para mantener buenas relaciones con otras personas. Esto implica dominar las habilidades sociales, capacidad para la comunicación efectiva, respeto, actitudes pro-sociales, asertividad, etc." (p. 27).[7] I concur with Tallón and Sikora (2011) in that these competences include: understanding others, political conciousness (it makes reference to power influence in groups), communication, cooperation, leadership, influence and conflict solving.

The main hypothesis of this article is that the flipped classroom methodology favours the development of autonomous learning and the acquisition of social competences in university students. Thus, the objectives of this study are the following: 1. To observe how flipping a grammar and a speaking class allows students to acquire grammar content, improve their speaking skills and develop social competences and 2. To know students' opinions about the methodology used in the teaching-learning process. The main research question in this article is the following: is the methodology proposed by the flipped classroom appropriate to help students acquire grammar content and improve their speaking skills at the same time that they develop social competences?

[7]Translation by the author: "[…] the ability to maintain good relationships with other people. This implies mastering social skills, effective communication skills, respect, pro-social attitudes, assertiveness, etc." (Bisquerra & Pérez, 2007, p. 27).

This article is organised as follows: section 2 is the literature review. This is followed by the methodology used in the study (section 3). Section 4 presents a practical proposal for flipping a language subject, specifically the sections devoted to grammar and oral skills. Section 5 offers the results of the questionnaire and the rubric used in this research. The article finishes with a discussion and some conclusions based on the study.

Literature Review

The flipped classroom model has been developed in the last decade in order to use the classroom time for discussion and for cooperative activities once students have worked at home (Bosch-Farré et al., 2024; Crespo Fernández, 2021; Goodwin & Miller, 2013; Milman, 2012). Thus, the flipped classroom involves blended learning; i.e., a combination of learning in the classroom and distance learning facilitated through a range of technological resources. This asynchronous approach means that the time in the classroom can be devoted to student-centred synchronous learning activities (O'Flaherty & Phillips, 2015).

The concept of flipped classroom was introduced by the high school chemistry teachers Jonathan Bergmann and Aaron Sams (Bergmann & Sams, 2012). They emphasized that teaching should focus on motivating students to learn in an autonomous way and on observing students' learning process, which involved making adjustments if necessary and offering students different ways of learning content (Bergmann & Sams, 2012). Consequently, teachers do not have a central role in the teaching-learning process because they mainly supervise students' work and guide them to work with the materials that they have before the lectures.

The Flipped Learning Network (2014b) has articulated four pillars of flipped learning: flexible environment (F), learning culture (L), intentional content (I), and professional educators (P) (F-L-I-P). In fact, 'F' involves diverse learning styles and gives students the opportunity to reflect on their own learning, including the main difficulties that they have.' L' highlights that the responsibility is on the student in the flipped learning model, which contrasts with traditional education where the teacher had a central role and was the main source of information. This means that teachers are guides, coachs or supervisors in the teaching-learning process. Therefore, 'I' involves the importance of students' development of conceptual understanding with materials that favour autonomous learning. Finally, 'P' concentrates on the importance of teachers in the process of flipping a subject because they have to monitor the teaching-learning process and to offer continuous and relevant feedback while students learn. This means that teachers have to be well prepared before the class so that they can guide students and reply to their needs (Baepler et al., 2014). Following Marshall and Kostka (2020): "As a professional educator, the teacher creates a flexible learning environment, conducts regular formative assessments both in and out of class, and shares ideas and reflects on teaching with their colleagues" (p. 3).

The methodology proposed by the flipped classroom means that students and teachers develop digital competences (Pozo Sanchez et al., 2020), which is an area

that requires further development and exploitation, following Singay (2020): "Flipped learning is an educational approach where learning moves from classroom to home, likewise group to an individual. The classroom materials are presented to learners using smartphones, videos, podcasts, and handouts in advance to read, watch, and listen at home" (p. 666).

In addition, flipped learning encourages innovative teaching at the same time that the classroom time is used for practising concepts that are introduced before in-class instruction (Cheng et al., 2020; Santikarn & Wichadee, 2018). In fact, flipping the classroom contributes not only to fostering active learning but also to increasing motivation (González Mujico & Lasagabaster, 2019; Hung, 2015). This method also increases interaction and active learning (Roach, 2014) and influences cooperation, innovation, autonomy and task orientation (Evseeva & Solozhenko, 2015; Strayer, 2012).

Chen et al. (2017) examined 46 articles on the effectiveness of flipped classrooms in medical education with different learning outcomes. Generally, studies agree on the positive effects of this methodology, such as the self-efficacy and responsibility of the students in these classrooms (Lai & Hwang, 2016). Self-efficacy is associated with students' academic success because students obtain better results than in traditional instruction at the same time as they improve their learning outcome (Abedi et al., 2019; Haghighi et al., 2019).

There are studies that focus on students' perceptions of the flipped classroom and on the reasons why they prefer the flipped methodology to the traditional one (Amiryousefi, 2019; Kostka & Marshall, 2017). The main advantages students see include working in their own way and having the possibility of watching the videos or working with the materials several times before class so that there can be more in-class practice (Alsowat, 2016). Students also emphasise that this methodology favours the development and integration of the different skills (Wu et al., 2017) at the same time that it promotes active and effective learning (Nouri, 2016). There are very few studies that apply the use of the flipped classroom in undergraduate linguistic courses (Martyniuk, 2019) or in grammar instruction in higher education (Almazán Ruiz et al., 2020).

Methodology

Course Description

This study is based on a core subject called English Language V that is taught during the first semester of the third year in the English Studies degree program at a Spanish university. The purpose is for students to develop the five skills in English in order to acquire an advanced level of English, level C1 in the Common European Framework of Reference for Languages (Council of Europe, 2020). There are four hours per week: one to work on reading and writing, another for grammar, and the last two hours for speaking and participating in oral presentations and debates. Of the three main sections in which the subject was divided, the second and third were flipped in order to give students opportunities to

be autonomous while they learned grammar and prepared oral presentations and debates. Consequently, the classroom was used to ask questions, to share the work previously done and to be involved in discussions.

Participants

During the academic year 2021–2022, 87 students were registered in the English subject mentioned. They were divided into two groups by administrators, considering alphabetical order, 50 in group A and 37 in group B. Sixty-nine were female and 18 were male. All of them had studied English in the previous academic years of the degree, and all had level B2. They were asked to use the platform provided by the university to have access to the online materials (grammar points on PowerPoint, list of videos and documents to prepare effective oral presentations) and to follow the instructions provided by the teacher to learn in a flipped way.

Research Instruments

The reseach instruments consisted of a questionnaire investigating students' opinions on the flipped classroom. The purpose of using the questionnaire was to see if the methodology was considered effective by students after their participation in the different activities (see Appendix 1). The questionnaire allowed obtaining some quantitative data and was completed at the end of the semester by all the students enrolled in the subject, i.e., the participants in this research. It consisted of nine questions: six multiple-choice questions and and three open-ended questions. The data obtained from the questionnaire were statistically analysed using Excel software (Microsoft Office), in order to obtain univariate statistical parameters.

Another instrument was a rubric used by the teacher while students were giving the oral presentation in the classroom (see Table 2). Students' answers to the same rubric that the teacher had used while observing the oral presentations were also part of the data. Students completed the rubric in a group tutorial. The teacher manually analysed the data of all the groups at the end of the semester, to compare the results of students' evaluations once the oral presentation was done with her own while students were sharing the presentation in the classroon (see section 5).

Procedure

Different activities were planned during the first semester of the 2021–2022 academic year to work on grammar and speaking in the subject English Language V, following the principles of the flipped classroom (see section 4). At the beginning of the semester the teacher prepared *PowerPoint* presentations in which the main aspects that would be revised in each of the grammar classes were outlined (see section 4.1). Then, students were asked to revise the *PowerPoints* and the explanations given in the grammar book (Hewings, 2013) before preparing the exercises. The teacher also provided students with a list of videos to reinforce grammar. Thus, the teacher applied the principles of the flipped classroom in different ways: 1. By giving the students the following materials before the class: a calendar with a list of topics and the weeks they

would be studied, a list of videos on grammar topics and *PowerPoint* presentations with a summary of the two weekly topics of English grammar. 2. By insisting on the need to reflect and write down the main difficulties they encountered in the weekly grammar topics before coming to class. Therefore, the teacher promoted prior critical reflection and logical deduction by the students about the grammar topics under study each week. Once the grammar exercises were corrected in the classroom and students asked questions, the teacher prepared some questions in *Kahoot* to revise the topics under study and to motivate students by introducing gamification in the classroom.

In addition, the section of the subject devoted to speaking and participating in oral presentations and debates was flipped because students were given instructions on how to prepare effective oral presentations at the beginning of the semester so that they could work autonomously. Then, the teacher asked them to organise themselves in groups of five people, and a distribution of the groups was done so that they could present one oral presentation and debate per week. In fact, this section has three stages: a pre-class stage where students have to organise the oral presentation, an in-class stage where students give the oral presentation in front of the teacher and their classmates and a post-class stage where students reflect with the teacher on the way the oral presentation can be improved and on the main strengths of the presentation.

When students were giving the oral presentations they had prepared in groups, the teacher used a rubric (see Table 2) to observe several aspects associated with their performance in the oral presentations and their development of social competences. The same rubric was also completed by the group in charge of the presentation every week, so that the teacher could contrast students' answers with her own at the end of the semester. Finally, the questionnaire that the students completed at the end of the semester provided information on their opinion about the activities in which they had participated and their relationship with the flipped classroom.

A Practical Proposal for Flipping a Language Subject

This section presents the main steps followed to flip the section of the subject English Language V devoted to grammar. In addition, section 4.2 explains how the section on speaking was flipped.

Flipping a Grammar Class

Students were given a calendar at the beginning of the semester with the assignments they had to prepare during the semester. This document also had the list of the two grammar topics they had to prepare each week during the semester from the book *Advanced Grammar in Use* by Hewings (2013). In most cases, the two grammar topics that were explained each week were related, as can be seen in Table 1.

Table 1. Grammar Topics Covered in English Language V

Weeks	**Grammar topics**
Week 1	45, 87: Articles and connectors
Week 2	53, 54: Relative pronouns
Week 3	40, 41: Subject-verb agreement
Week 4	42, 43: Subject-verb agreement and compound nouns
Week 5	46,47: Articles
Week 6	32, 33: Reported speech
Week 7	66, 67: Adjectives
Week 8	68, 69: Adjectives
Week 9	70, 71: Adjectives +to inf., ing, etc. Adjectives and adverbs
Week 10	22–23: Passive voice
Week 11	74, 75: Adverbs
Week 12	Writing exams in the classroom
Week 13	76, 99: Adverbs and inversion
Week 14	77, 100: Adverbs and inversion
Week 15	Revision and doubts

During class time, the teacher started the lecture by asking if the students had any questions about the PowerPoint*s* of the topics that were studied that week (students had them in advance). She also asked them about the list of difficulties they had prepared at home, and they were discussed. The teacher offered examples on the blackboard so that students could apply their knowledge. After reviewing the grammar in this way and answering the possible questions, the exercises in the book were corrected in order to put into practice the aspects already revised theoretically.

It should be noted that the teacher could focus on the most important grammatical points or could complete some aspect that was not sufficiently explained in the book because students had the grammar outline beforehand. In addition, the objective of giving students a list of videos related to the grammar topics under study (see Table 1) was that both students who had a higher level and those who had a lower level of English could go deeper into the revision of the grammatical aspect outside the classroom. Moreover, the videos offered the opportunity to work on listening, a fundamental skill of the subject.

The last five minutes were used to revise the main aspects of the lesson using *Kahoot* so that students could choose between a correct and an incorrect sentence, which allowed the teacher to see if the grammatical aspect under revision was understood or if further revision was needed. *Kahoot* was chosen because it is a gamification tool well known in teaching and it increases students' motivation by making the classroom dynamic interesting while revising the main grammatical points in each class. In addition, this tool is free and easy to use.

Kahoot can be used from any cell phone, and it allows students revising or putting into practice what they had learned in a playful way. Thus, it integrates games, learning and new technologies in the teaching-learning process. *Kahoot* promotes competition in the classroom because the student who wins is the one who chooses the right answer in the shortest possible time. The right answer is given after each question, the results that each student has and the mark obtained.

Flipping a Speaking Class

Students had to prepare cooperative oral presentations on social topics of their choice, following the guidelines given by the teacher at the beginning of the semester. The teacher chose cooperative oral presentations to evaluate students' oral skills, due to the high number of students registered in the subject. This activity was framed in a flipped methodology because students had to distribute tasks in the group, manage time, take decisions, distinguish relevant from secondary information and be co-responsable so that the final task was successful outside the classroom.

In order to make this cooperative activity successful, the teacher explained the main characteristics of effective oral presentations and how to quote in-text references at the beginning of the semester. She also explained how to write an entry in the bibliography following the APA system of citation. This was essential to avoid plagiarism in the PowerPoint presentation and in the outline that students had to give to the teacher with the following information: a summary of the presentation, the main vocabulary they have learned, a text on the topic of the oral presentation and the references used.

The teacher also insisted on the importance of time management and on the equal distribution of tasks during the teaching-learning process. Students were free to choose a topic of their choice. The only guidance that the teacher gave students on the selection of the topic was that they had to work on a social topic and it was essential to use advanced vocabulary in the *PowerPoint* presentation and in their oral discourse.

At the same time that the teacher evaluated each presentation, there was a group of students that also evaluated their classmates. In this way, students were given an opportunity to be empowered with self- and peer assessments, to develop social competences such as leadership and communication and to have the opportunity to speak in the classroom. The group that was evaluating had to give feedback to their classmates before the teacher did. Then, the teacher offered her feedback. Finally, once the oral presentation was given, students had a group tutorial with the teacher to discuss some specific aspects such as the main grammatical mistakes or the difficulties that the group had in preparing the presentation. Moreover, students had to self-evaluate and justify their grade, taking into consideration the rubric whose analysis is presented in section 5.

The cooperative oral presentations that the students prepared offered them a global vision by giving them the opportunity to delve into a social issue of their choice. They were normally related to a social situation that needed to be improved in society. Consequently, the presentations were associated with certain social realities and with cultural issues that could arouse in students not only interest but also the need to assume a commitment in order to improve or transform the realities present in the selected topics. Examples include animal rights, ecology, integration of immigrants or the need for education to be a fundamental right in all countries. In this way, social responsibility is increased, which can be associated with responsible social behaviour (Porto, 2015).

This activity also helped students to have a broader vision of the world and a more open mind regarding the subject of study, by offering the possibility of better understanding of other realities, thanks to the research on the subject, before giving the presentation in class. Thanks to this activity, students acquired social competences such as communication, leadership, empathy, conflict resolution and understanding realities other than their own. They had to negotiate the topic of the presentation, make decisions about the organization and search for information. In addition, students acquire knowledge and vocabulary on the selected topic.

Results of the Rubric and of the Questionnaire

The teacher prepared a rubric with a Likert scale where 5 as the highest score. She completed this while observing students' participation in oral presentations. It was also completed by the students in charge of the oral presentation and debate every week in a group tutorial. Once all the groups had presented their work, the teacher analysed the results of her answers and compared them to the students' answers to the same rubric. There were four general aspects under observation. The percentage in the first line in Table 2 indicates the teacher's evaluations of the students' oral presentations, and the second line shows the students' evaluations.

Table 2. Rubric Used by the Teacher in the Classroom

Aspects under observation	**Likert scale results**				
	1	2	3	4	5
1.Students' participation and engagement with the task	0% 0%	0% 0%	12.08% 6.59%	32.96% 21.97%	54.94% 71.42%
2.Constructive interactions and discussions in the classroom based on the materials provided/oral presentations prepared	0% 0%	0% 0%	8.79% 8.79%	39.56% 34.06%	51.64% 57.14%
3.Management of social conflicts in the groups/classroom	0% 0%	0% 0%	6.59% 6.59%	49.45% 36.26%	43.95% 57.14%
4.Social competences observed such as communication, cooperation or leadership	0% 0%	0% 0%	6.59% 8.79%	43.95% 47.25%	49.45% 54.94%

The results presented in Table 2 show that the average of the answers of the teacher and the students are sometimes quite similar. This is the case in items 2 and 4. The number of answers 4 and 5 on the scale offer a similar percentage. The students offer a slightly higher number of answers in number 5 on the scale in the four items, whereas the average answers of 4 in the scale in items 1, 2 and 3 are a bit higher than those proposed by students. These differences are justified because the said items could only be observed and evaluated by the teacher while students were giving the oral presentation in the classroom and were participating in the debate that followed it. For instance, considering item 3, the only times the teacher was aware of conflicts in the group were when students sent tutorials and informed

the teacher about a conflict associated with the lack of involvement of group members. That happened only twice during the semester. The rest of the time, the teacher could only observe conflicts when there were differences of opinion while students were participating in debates.

Thus, students' answers in the rubric focus on the whole teaching-learning process, whereas the teacher concentrates on the implementation of the activities in the classroom. The last item on the acquisition of social competences was essential so that students could see that by preparing oral presentations and debates they were not only working on oral skills, but they were also acquiring competences that are essential in the labout market and in life, such as communication, cooperation and leadership.

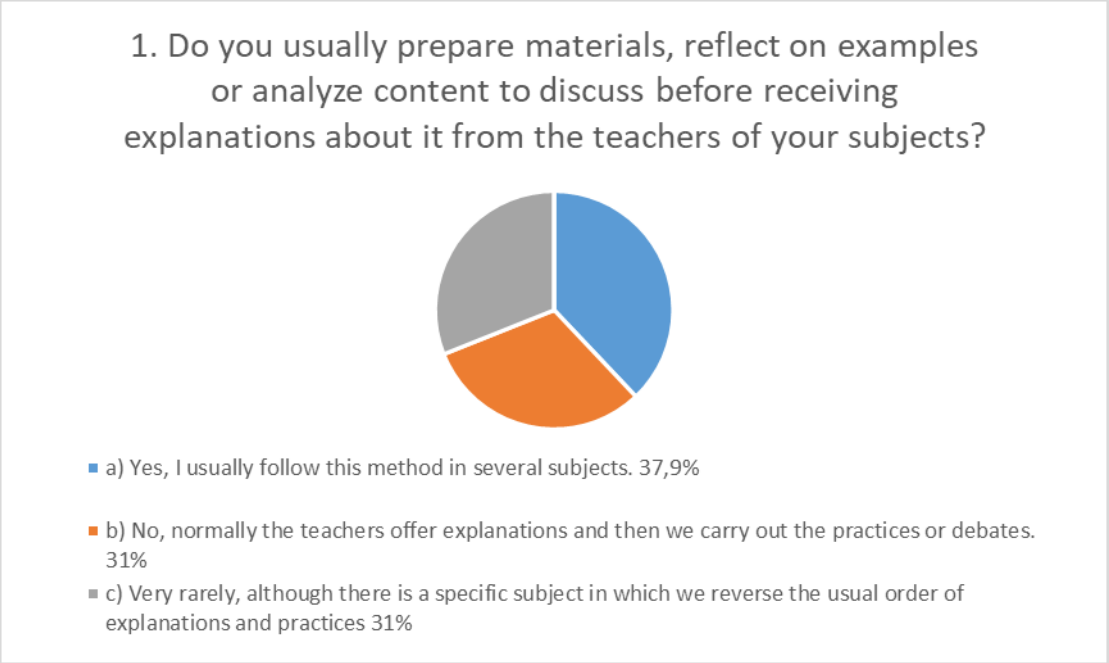
The results in Table 2 show that numbers 1 and 2 on the scale were not selected by the teacher or by the students in any of the items, and the higher percentage in number 3 is 12.08%. This shows that both students and teacher can observe their/ students' progress in the items under observation during the teaching-learning process remarkably well.

As mentioned in section 3.3, apart from the rubric, a questionnaire was carried out anonymously. The aim was to discover university students' opinions about some aspects of the flipped classroom. For this purpose, nine questions were formulated to configure the questionnaire. It begins with a general reflection on the identification of the method known as flipped classroom. Next, it delves into more specific aspects of the real application in autonomous learning and other aspects (see Appendix 1). The last three questions are open so that students can express their own opinions freely.

The first question refers to the habit of analysis and reflection on the contents studied prior to the explanations provided by the teacher. The equal nature of the three responses is still surprising, probably due to the "coexistence" of methodologies that surely converge in the degree in which the inverted classroom has a role in some subjects. However, the flipped classroom is not a method so much in other subjects because the traditional methodology was more common.

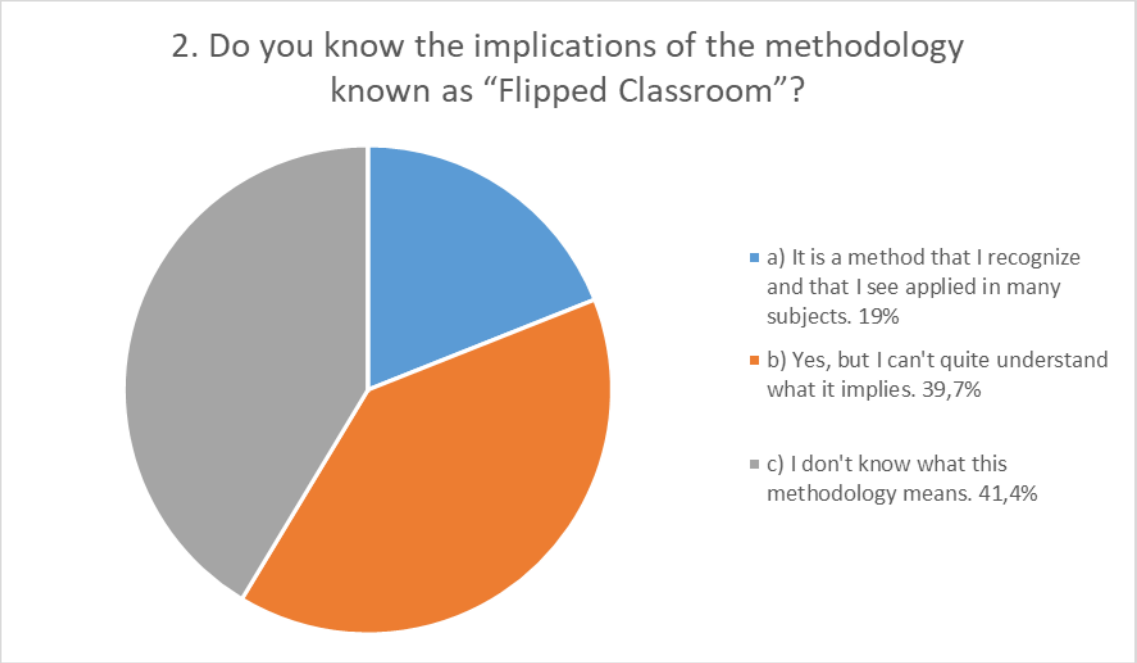
Thus, 37.9% identify this methodology in several subjects (with a slight majority over the two remaining percentages), but 31% do not perceive the approach as such, and 31% of the students rarely see reflected this method in their regular classes, in which reversing the conventional order between teachers' explanations and students' reactions is not common in their opinion, as can be seen in Figure 1.

Figure 1. Results of Question 1



In question 2, however, most of the students do recognize this methodology and do perceive it in its practical application with respect to many subjects. Specifically, 41,4% of those surveyed confirm this, while 39,7% know the method but do not quite understand what it implies. Finally, for 19% of the students, this methodology is quite opaque, because they claim not to know what it really means, as can be seen in Figure 2.

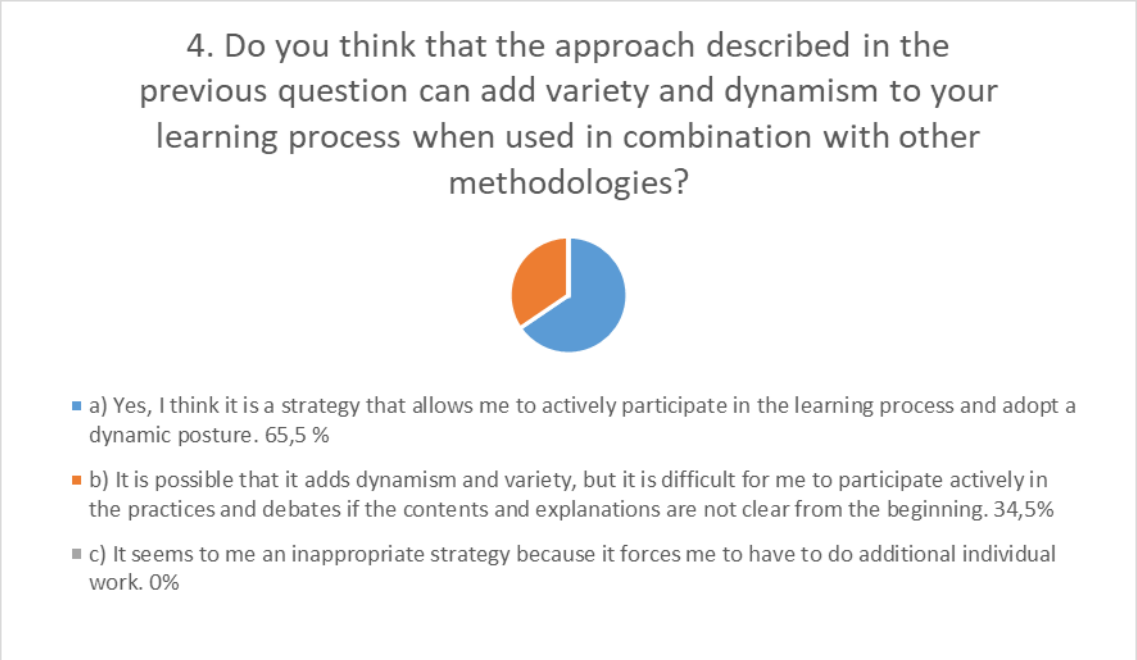
Figure 2. Results of Question 2



I also wanted to determine if the initial reflection prior to the teacher's explanations facilitated autonomous learning, problem solving and critical thinking (question 3). On this occasion, curiously, an overwhelming 87.9% of the students answered affirmatively and thereby ratified the value and usefulness of this method along with other approaches. However, 10.3% admitted that it may be an effective option, but they expressed distrust of this methodology because it moved away from the more traditional approaches. A tiny 1.8% of the respondents did not find a useful application of this methodology by ensuring that the learning process could only start from the teachers' explanations.

Moreover, in question 4, this didactic strategy provided a certain variety and dynamism to the learning process in combination with other methodologies for 65.5% of the students. The fact that students are active and dynamic in the teaching-learning process is essential so that authentic learning takes place. In this regard, it is still significant that the majority conceive this method as an accurate and dynamic formula in combination with other approaches. However, the remaining 34.5% admitted the latter, but they mentioned the difficulties involved in active participation in debates if there were many initial doubts regarding the content discussed. In any case, none of the participants chose to consider this strategy as inappropriate in itself (answer c). Therefore, with these data we can consider ways to rethink some aspects of this methodology if applied in the future according to the didactic circumstances of each session or specific content (see Figure 3).

Figure 3. Results of Question 4



Regarding the usefulness of the methodology attributable to the flipped classroom as a guide to identify students' strengths and weakenesses in order to guide them in an autonomous learning process (question 5), students considered in

63.8% of the responses that the reflections and practices prior to the theoretical explanations of the teachers can guide the teaching-learning process, thanks to the fact that the initial autonomous analysis allowed identifying preliminary knowledge on the subject at the same time as it can be adapted to students' circumstances.

Nevertheless, 31% of those surveyed admitted the convenience of this autonomous analysis in advance but also alluded to the lack of time to continue with subsequent actions when taking an active role in the teaching process. A small percentage of students, 5,8%, did not consider this methodology to be useful, considering that it did not provide relevant information for teachers, who will ultimately only assess the final results. However, although in the latter case, answer c, there were not many students who shared this opinion, the teacher could consider undertaking methodological changes in the future so that most students can benefit from it.

The answer to question 6 shows that for 84.5% of the students, the contribution of *PowerPoint* presentations and written materials on grammatical content at the beginning of the semester had been helpful to revise grammar for the weekly sessions. However, for 12.1% of those surveyed, this reference material had not been useful, whereas 3.4% indicated that it had been useful for them to some extent. It is not known how thoroughly all respondents had been able to revise these grammar presentations. It probably depended on their level of English. In fact, the level was heterogeneous although all students had studied English in the degree program.

Analysing answers to the first open question (question 7) gives the impression that students saw the usefulness of the inverted classroom because they believed that grammar was taught in the right way. Students refer to possible strategies that could be implemented to optimize the grammar sessions in the subject and to promote the achievement of level C1. Some students suggested that there should be more opportunities to discuss problematic examples and to prepare debates on grammar teaching at different educational levels. In addition, some students mentioned the convenience of including more playful activities in the sessions so that the gamification strategy proposed is not based only on *Kahoot*. In general, students considered very positive the inclusion of active methodologies that add dynamism and variety to the teaching-learning process.

Regarding question 8, students considered the following advantages of the methodology proposed by the flipped classroom: the possibility of organising their own time before the lecture. In fact, many students mentioned that having the materials in advance was very useful to prepare the grammar exercises. They also highlighted that they felt active and dynamic while they were learning, i.e., they were the protagonists of the teaching-learning process. In addition, they commented that they had improved working autonomously and that this methodology helped them see the teaching-learning process as a whole, because lectures were not effective if they did not prepare what was requested in advance.

Finally, regarding question 9 and the main disadvantages of the flipped classroom, many students mentioned that they had more responsibility in their learning, whereas the teacher had less responsibiliy. In this sense, they said that the teacher's explanations did not have a relevant role in the classroom and that they

missed some detailed explanations sometimes. Moreover, some students mentioned that they had difficulty organising their own time, which was not beneficial for this methodology. In fact, there were students that needed help to develop autonomous learning.

In summary, after analysing all the answers in the rubric and in the questionnaire, the results show that students developed social competences at the same time as they acquired grammar contents and improved their speaking skills with activities framed in the flipped classroom methodology. The number of answers 4 and 5 provided by the teacher and by students on the Likert scale used to evaluate the aspects under observation in the rubric (see Table 2) showed that both were aware of the acquisition of social competences, the engagement of the task and other aspects. Similarly, the results of the questionnaire also showed that students considered the flipped classroom methodology a useful and effective method in the teaching-learning process.

The questionnaire has been a useful instrument in giving students the opportunity to assess the extent to which the inverted classroom methodology, in combination with other methods, approaches or strategies, contributes to facilitating students' learning. Therefore, thinking about the usefulness of combining different teaching methodologies is already a step forward towards methodological innovation as a global academic topic.

Discussion

The flipped learning experience described in this article involves engagement with the contents and interaction between students and teachers (Cavage, 2019). The use of activities framed in the methodology proposed by the flipped classroom allows students to organise their own learning, which helps to give them autonomy in the teaching-learning process (Bergmann & Sams, 2012, 2014). In fact, this active methodology contributes to the engagement of students in meaningful activities without the teacher having a central role while they were learning. Thus, they were active and became the centre of the teaching-learning process. Consequently, the main teacher's roles were that of supervisor or facilitator.

By flipping the speaking and the grammar class, students developed autonomous learning because they had to manage time to prepare the tasks and effectively use the different resources provided. Consequently, the activities presented in this article make the most of the classroom time in order to promote active learning (Roach, 2014). This requires the materials and activities before the classroom time to be very well designed so that the teaching-learning process is effective and students acquire significant learning (Santikarn & Wichadee, 2018).

Classroom discussion is promoted as a way of giving students a central role in the teaching-learning process, which is one of the key ideas in the methodology proposed by the flipped classroom (Bergmann & Sams, 2012). Thus, active relationships are encouraged so that students acquire different types of competences while they learn, which favours making the teaching-learning process dynamic and adapted to students' needs. Consequently, social competences such as cooperation,

communication, conflict solving and leadership are developed during the teaching-learning process in different ways: firstly, in a speaking class, by dividing the tasks to prepare the oral presentations in an equal way, by making decisions on how to organise the topic, on how to select the references and the multimodal resources used to prepare the presentations, on preparing the questions for the discussion that took place in every class after the oral presentation, among others. In fact, students benefited from working autonomously because they had to take decisions and organise their learning process, which involved the acquisition of the said competences.

Secondly, social competences were reinforced in the grammar classes. Students had to discuss problematic examples in the classroom and then distinguish correct and incorrect sentences with *Kahoot*, providing an explanation with the reason for their answers. Therefore, this task goes beyond grammar, because students interact and engage with the task by having to explain the reason for right answers. The discussions also consisted of thinking of the possible reasons why students could choose the wrong answer and on deciding the best ways to explain the problematic examples so that nobody had doubts.

The fact that the grammar topics were prepared individually and the oral presentation was prepared in a cooperative way proves that the flipped classroom is useful and effective in both cases. The flipped activities presented in this article show that this methodology goes beyond watching videos, because it promotes autonomous learning, gives students an active role in the teaching-learning process and adapts to different learning styles (Crespo Fernández, 2021). Consequently, this methodology gives students opportunities to evaluate, apply, analyse and summarize; it goes beyond the acquisition of content (Lee & Wallace, 2018).

Kahoot is a very good tool to check students' understanding of grammatical aspects. Thus, *Kahoot* was considered a useful tool for the teacher and students because it showed if the grammatical point under revision was properly understood or further explanation was necessary. For instance, the day the topic subject-verb agreement was revised in the classroom, the teacher explained that when the subject follows the verb, it must agree with it as we can see in this example: "Among the important researchers was a friend of mine". Students said that they understood the theory associated with the example. However, when students were asked at the end of the class to answer using *Kahoot* which of the following senteces was correct: a) Among the politicians was a friend of mine and b) Among the politicians were a friend of mine, it was surprising that one-third of the students in the classroom chose sentence b) because they understood that 'Among the politicians' was the subject.

Using *Kahoot* framed in the principles of the flipped classroom made it possible to use more lecture time for the application of content. Consequently, the teacher used to ask the students who had chosen the right answer to explain the reason for their choice to the other students. The explanation provided by students to justify their answer is very important in confirming that significant learning had taken place and that they were able to explain to other students the grammar topics under study. Moreover, the teacher reinforced grammatical aspects using other examples whenever necessary. Thus, *Kahoot* allowed the addressing of

grammatical aspects that were not clear immediately, because students had to choose one of the examples, and the results showed if students had understood the topic under study or if further explanation or practice was needed.

The fact that students had PowerPoint with the main ideas of each topic and videos does not mean that flipping the subject consisted only of reading and watching them before class. These materials were given importance because they were based on the theory required to prepare the exercises that students had to complete every week. In fact, the PowerPoint presentations had a key role in knowledge transmission because they included essential information for the practice. However, the list of videos was prepared by selecting them from the internet, and some went beyond the grammatical point under study.

The main limitations of this study are the following: firstly, the results are limited because they are based on the students enrolled in only one subject during one academic year. Secondly, the rubric could have more items to be evaluated; similarly, more questions could be added to the questionnaire so that students could offer more opinions on the methodology proposed by the flipped classroom. In this sense, some recommendations for future research are the following: it would be convenient to organise focus groups or interviews with students for future studies so that students could explore more aspects of the flipped classroom methodology. Moreover, other studies could explore if apart from social competences, personal competences were also developed with the proposed methodology.

Conclusion

The flipped learning experience presented in this article emphasises the importance of using classroom time for the application of knowledge. Thus, knowledge transmission takes place outside the classroom using the materials provided by the teacher in advance, using the university platform. The preparation of homework is essential so that students can apply theory to practice and identify questions before the lecture. In this way, the methodology is student-centred because students acquire knowledge through assignments before the class (for instance preparing oral presentations or grammar exercises), they manage their time and they use the resources provided at their own pace. Consequently, in-class time is used to ask questions, to discuss and to work in a cooperative way.

The proposed methodology adds dynamism to the classroom. The time devoted to introducing content during the lectures is substituted by having students study before class. In this way, they can apply knowledge to the practical activities that they have to prepare as homework. Also, having gamification through *Kahoot* adds dynamism to the classroom, because the questions in *Kahoot* contribute to having discussion in class, problem solving and analysis of examples.

In this sense, it is considered that framing the teaching-learning process in the principles of the flipped classroom, as suggested in this article, favours students' empowerment by offering them the opportunity to manage their time outside the classroom so that they can make the most of the lectures. This is essential in the oral presentations because students are responsable for teaching on a social topic

of their choice to the rest of the students, which involves working hard before the day of the presentation. This was also crucial in the grammar lectures because their effectiveness depended on students' revision of the grammar before class and on having done the exercises for each topic in order to put what they learned into practice, to apply the theory to the practice and to observe possible difficulties or questions that may arise in class.

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Appendix 1. Questionnaire Conducted with English Language V Students on Aspects Related to the Methodology Proposed by the Flipped Classroom

1. Do you usually prepare materials, reflect on examples or analyze content to discuss before receiving explanations from the teachers of your subjects?
a) Yes, I usually follow this method in several subjects.
b) No, normally the teachers offer explanations and then we carry out the practices or debates.
c) Very rarely, although there is a specific subject in which we reverse the usual order of explanations and practices.

2. Do you know the implications of the methodology known as "Flipped Classroom"?
a) It is a method that I recognize and that I see applied in many subjects.
b) Yes, but I can't quite understand what it implies.
c) I don't know what this methodology means.

3. Do you think that reflecting on grammar issues before receiving the relevant explanations from the teachers is an appropriate formula to develop autonomous learning, problem solving and critical thinking?
a) Yes, I believe that this option and other methods can be helpful.
b) It is possible that it is an effective option although I mistrust methodologies that are not traditional.
c) I do not think that this option will be of help to me at all, because I can only begin to work or analyze concepts from the explanations of the teachers.

4. Do you think that the approach described in the previous question can add variety and dynamism to your learning process when used in combination with other methodologies?
a) Yes, I think it is a strategy that allows me to actively participate in the learning process and take a dynamic posture.
b) It is possible that it adds dynamism and variety, but it is difficult for me to participate actively in the practices and debates if the contents and explanations are not clear from the beginning.
c) It seems to me an inappropriate strategy because it forces me to have to do additional individual work.

5. Do you think that with the activities, reflections and practices prior to the explanation of the theory and the contents, the teacher can identify your strengths and/or the aspects that you should reinforce to guide you in your learning process?
a) Yes, because the conclusions of my autonomous analysis provide information on the degree of knowledge and understanding I have on the subject.
b) Sometimes my participation and my autonomous analysis can give information about the level of understanding or confusion that I have, but sometimes there is no time to prepare the material well and the previous practices are not meaningful.

c) I do not believe that the previous practice, the preliminary debate or my personal analysis provide useful information to the teachers, because in the end they will evaluate me by my final results.

6. Has it been useful for you that the teacher of the subject shared the grammar *PowerPoint* presentations with you at the beginning of the semester so that you could study/consult them before the weekly grammar class?
a) Yes, it has been useful to me.
b) No, it has not been useful to me
c) To some extent it has served me.

7. How else do you think grammar classes can be taught in the subject so that you get the most out of them? (Keep in mind that the C1 level grammar is a review of the aspects studied in previous courses).

8. In your opinion, what are the main advantages of the methodology known as "Flipped Classroom"?

9. In your opinion, what are the main disadvantages of the methodology known as "Flipped Classroom"?

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Development of Critical thinking through the Creation of Mathematical Problems

By Valéria Švecová[*], Marta Balgová[±] & Veronika Uhríková[°]

Through creative thinking, it is possible to acquire new attitudes and a view of the world, not only of mathematics but from several sides (Kamp, 2016). Creativity in mathematics can be defined as a process based on sensitivity to problems, deficiencies, gaps in knowledge and sensitivity to identifying missing elements, revealing difficulties in finding solutions, making estimates, formulating hypotheses, and verifying them and then forming a conclusion (Mann, 2006). The concept of critical thinking is closely related to creativity. Its essence, not only in mathematics, lies in the way of formulating and asking questions. Broader assigned tasks or complex problems lead students to new data and knowledge, which naturally creates the ability to think critically. The paper focuses on problem posing and the development of critical thinking through the creation of tasks based on Bloom's taxonomy and criterial testing requirements. Part of the paper will also be a description of the process of creating math problems, their evaluation, compiling a test based on various criteria, diagnosing students based on the results and proposing further work with students.

Introduction

Nowadays, when, among other things, emphasis is placed on testing students in different grades of elementary school, teachers are also required to have a creative approach to creating assignments. Creating tasks is a creative and demanding process, especially if it is necessary to create tasks according to precisely defined criteria, e.g. Bloom's taxonomy. In practice, we encounter that teachers have a problem with this activity. Therefore, we consider it necessary to emphasize the creation of tasks already in the training of mathematics teachers, whether in the 1st or 2nd grade of elementary schools.

Through creative thinking, the solver/student acquires new attitudes and insight into the world, not only mathematics, but from several sides (Kamp, 2016). Creativity in mathematics can be defined as a process based on sensitivity to problems, deficiencies, gaps in knowledge, and sensitivity to identifying missing elements, revealing difficulties in finding solutions, making estimates, formulating hypotheses, and verifying them, and then forming a conclusion (Mann, 2006). The concept of critical thinking is closely related to creativity. Its essence, not only in mathematics, lies in the way of formulating and asking questions. Broader assigned tasks or complex problems lead pupils/students to new data and knowledge, which naturally creates the ability to think critically.

In the PISA monitoring of mathematical literacy, Slovak students achieve long-term results below the OECD average (PISA, 2018). Slovakia as well as some other

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countries, e.g. Denmark responded to the PISSA results by introducing a set of national tests (Andersen & Nielsen, 2016). So far, nationwide measurements of pupils' educational results in mathematics have been implemented in the Slovak Republic with the aim of maximum objectivity and differentiated assessment of pupils' performances - normative tests. They are comparative tests, the aim of which is to create a ranking of the tested students according to their success in the given test. Part of the ongoing education reform in Slovakia will also be innovation in the evaluation of educational results, primarily using criterion-referenced tests. In Sweden, research was conducted to examine the relationship between TIMMS testing and Swedish national measures. The result is a very strong correlation between the two tests, meaning that if a student was successful in the national testing, they were also successful in the TIMMS measure (Wiberg, 2019). This is also the reason for changing the national testing in Slovakia, we want to get closer to the PISA and TIMMS measurements. The goal of the contribution was to bring closer the process of creation and evaluation of test tasks suitable for national testing for pupils of the 3rd grade of primary schools.

Curricular reform is currently underway in Slovakia. Its aim is to create educational content organized in three multi-year cycles in primary schools. The intention is that teaching, instead of handing over ready-made information, creates situations in which students can interpret information in confrontation with real experience (Ministry of Education, Slovak Republic, 2023).

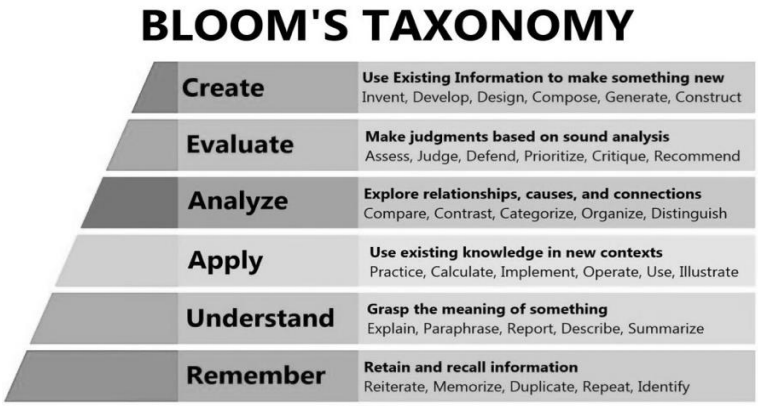
The aim of the article is to bring closer the process of creation and evaluation of tasks suitable for the prepared criterion tests in mathematics for the 3rd grade of elementary school (9-10 years) within the framework of the planned curricular reform. Curricular reform also includes innovation in the evaluation of educational outcomes through new testing methods. The aim of our research is to create a tool for criterion testing in mathematics. The final nationwide criterion testing of third graders will be in 2026. Until then, it is necessary to create tests, pilot, evaluate and possibly change individual tasks.

As stated by (Ficová, Pichaničová, 2023) criterion tests are created with the aim of reflecting on the absolute performance of the student. The task of such tests is to check the level of the student's knowledge and abilities in a precisely defined content area. However, the performance of the tested pupil is not compared with the performance of other pupils. The goal is to decide at what level the student controls the educational content and competencies - from the lowest level to the highest. The tests prepared in this way reflect the extent to which the student mastered the specified subject area, what is the minimum, medium, or optimal standard in the given content; to what extent the student knows what he is supposed to know; which specific parts of the curriculum content need to be focused on during tutoring. When constructing tests that are aimed at absolute performance, it is necessary to identify the subject matter that the student must master without problems. This curriculum is subsequently transformed into test tasks. To verify the mastery of a certain subject matter, it is required that each tested phenomenon be covered by a larger number of test tasks. They then need to be piloted, verified, and evaluated. Based on the evaluation, the task can then be included in the final test.

Literature Review

Problem posing and problem solving are one of the important topics in mathematics education. Problem posing covers a whole group of new problems that relate to creating a problem or reshaping an already formulated problem. Problem posing can also be used as a diagnostic or evaluation tool, which helps teachers to reveal deficiencies and obstacles in students' knowledge. Problem posing has the potential to be used as a diagnostic/evaluation tool (Papadopoulos, 2021). Both methods have the potential to improve the educational process at the primary level by strengthening students' problem-solving, creativity and independent thinking skills. Their effective use depends on teacher preparation and appropriate integration into the curriculum. According to Tichá and Hošpesová (2013) based on the raised problems, it is possible to examine both the level of understanding and the difficulty of a specific mathematical concept. Not all tasks are equal if we assess them from the point of view of their demands on the cognitive activities that need to be performed when solving them. Correct problem posing is very important for effective mathematics teaching. Teachers must also be able to formulate and set meaningful mathematical problems for their students. The problems that a teacher poses can affect the learning of mathematics in the classroom and "their other mathematical goals for the classroom" (Ferrini-Mundi, 2000, p. 53). Teachers can use problem-based tasks to find out how their students understand and apply mathematics in real life (Cai & Hwang, 2002; Cai & Hwang, 2020; Kotsopoulos & Cordy, 2009). Research by Hamidi, Soleymani, Dazy, & Meshkat (2024) also points to the connection between problem posing and problem solving on TIMMS measurement. Many experts from practice, as well as ministries of education of several countries, try to incorporate problem posing into teaching to increase the level of mathematical literacy as part of curricular changes (e.g. Brown & Walter, 1983; Healy, 1993; Ministry of Education, Slovak Republic, 2023). We can use different taxonomies by problem solving. Bloom's taxonomy is used in our conditions when assessing cognitive demands. The framework elaborated by Bloom and his collaborators consisted of six major categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Armstrong, 2010). In 2001 Bloom's taxonomy was revised (Figure 1).

Figure 1. Revised Bloom's Taxonomy



Source: Drew (2023)

Methodology

Three pilot tests were created and evaluated in 2023. Each one consisted of 30 tasks. We present two of them passed pilot testing and subsequent evaluation.

Since tasks from criterion tests can be repeated, they will not be published. After testing, the tasks that will contain them will be selected. The same principle is also used in the international PISSA or TIMMS tests.

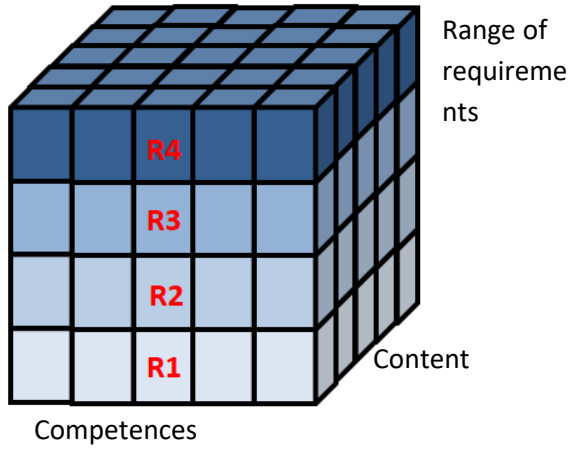
Each created task, which is included in the database, contains a table. It contains the characteristics of the task according to the theoretical framework, as well as the description of the task itself.

Mathematical problems for criterion tests are created based on a theoretical framework.

The theoretical framework is created due to the need to identify each task that is included in the task database. This database is then used to compile individual criterion tests. The creation of the theoretical framework was based on a holistic model that is uniform for all areas of mathematics teaching and levels of education. Existing frameworks used in mathematics education worldwide (PISA, TIMMS, VERA model, existing models in the USA and other countries) served as inspiration (Švecová, Balgová, 2023).

The theoretical framework contains four levels of the range of requirements (characteristics of tasks and their cognitive level) and five levels of competence, each of which has 3 more sub-levels. All domains are mutually independent (or existing dependencies are not intentional). (Figure 2).

Figure 2. Theoretical Frameworks' Model



Source: Ficová & Pichaničová (2023)

The characteristics of the framework for assigning tasks for the 1st cycle are shown in Table 1.

Table 1. The Characteristics of the Framework

	Range of requirements	**R1**	basic understanding, direct application of concepts
		R2	the need to determine a method, an algorithm
		R3	connection of several areas of mathematics, interdisciplinary relations
		R4	evaluation of correctness, truth
Mathematical competences	*Communication*	**C1**	understanding – 1st and 2nd level of Bloom`s taxonomy
		C2	application – 3rd level of Bloom`s taxonomy
		C3	analyse – 4th, 5th level of Bloom`s taxonomy
	Argumentation	**A1**	assess the correctness of calculation procedures
		A2	assess the relevance of the results
		A3	argue the truth
	Symbolic language	**S1**	standard notations, formulas
		S2	work with several formulas, find connections
		S3	complex statements, non-standard representations
	Modelling and mathematization	**M1**	recognize a known model
		M2	recognize a less known model
		M3	create, verify the model

Table 1 shows the two dimensions of the model from Figure 2. Table 2 focuses on the 3rd dimension – content standards for 1st cycle.

Table 2. The Characteristics of content Standards

Component		Content standard
I.	Numbers and operations with numbers	Natural numbers up to 10.000
		Addition and subtraction of natural numbers up to 1,000
		Multiplication and division of natural numbers up to 1000
		Numerical expressions in problem solving
II.	Dependencies, relationships and working with data	Basics of working with patterns and sequences
		Basics of working with dependencies and relationships
		Basics of solution elementary combinatorial problems
		Observation of elementary probabilistic situations
		Basics of working with data
III.	Geometry	Orientation in plane and space
		Basics of exploring 2D geometric shapes
		Basics of exploring 3D geometric shapes
		Elementary measurement procedures
		Basics of exploring and creation of symmetrical shapes

We used the IRT model for statistical evaluation of the criterion test. IRT (Item Response Theory) is an alternative to classical test theory (CTT) and allows to find out the properties of items that classical test theory does not provide. The

IRT models were selected in designed and evaluating of tests as the main method for several reasons. First, one advantage of IRT models over linear factor analytic methods is that information from examinee response patterns is analysed as opposed to the more limited information from correlation matrices. Second, nonlinear models such as IRT models may better reflect the relationship between item performance and the latent ability. Third, the multidimensional IRT models have been used to assess dimensionality of tests in which items reflect different skills, knowledge, or cognitive processes (Švecová et al., 2022). However, it has stronger prerequisites for use. IRT models with one latent variable use two assumptions:

- unidimensionality – the respondent's probability of answering an item is influenced by only one of his characteristics and any other influences are excluded,
- local independence – apart from the characteristics of the person, the influence of other test items on the answer is not considered (Švecová et al., 2022).

The 2 – Parameter Logistic model generalizes the unidimensional model by adding a new item parameter known as the discrimination parameter (Tendeiro, 2017). We compared unidimensional and 2-PL models for evaluation our test:

- The unidimensional model: we assumed that behind the different types and contents of tasks there is one common ability.
- The 2-Parameter Logistic model: we assumed that there are two distinguishable abilities behind the different types and contents of tasks.
  The comparison of 1- and 2-dimensional model (full test):
- We modelled two dimensions Geometry, measurement and Addition, subtraction (thematic unit).
- Dimensions were equally represented (24 items in each)
- Adding the 2nd dimension will slightly improve the fit of the model with the data, however, the correlations between the dimensions are very high (r = 0.944)
- The implementation of factor analysis also confirms the assumption of one-dimensionality.
  The unidimensional model seems to be more suitable for our data.

When verifying the task, its unsolved, difficulty, sensitivity and success were determined.

Results and Discussion

We present the characteristics of two of our created tasks, which were included in the pilot test intended for 3rd grade students (end of 1st cycle).

Table 3. Characteristics of the task Shopping in Diagon Alley

Shopping in Diagon Alley	
Level:	1st cycle
Performance standard	Solving application problem related to orientation in a table
Type of task	open
Theoretical framework	
Range of requirements: R2 – the need to determine a method, an algorithm. Mathematical competences C2 – understand simple content and apply calculation. S1 – identify relevant information in the text. M1 – acquire and use known models.	
Task's characteristics: Knowledge of numbers and operations with their is required when solving the problem. A pupil is expected to find, link, and analyze data from the text and the table. A basic understanding in a real-world context is required. The task is aimed at identifying the necessary data from the table. The table also contains redundant information.	

As can be seen from Table 3 the task was focused on working with a table and text. Three hundred and forty-six pupils from 39 schools throughout Slovakia solved the test with this task. Of the total number of pupils, there were 179 boys and 167 girls. Likewise, during the statistical processing, the seat of the school was also considered, i.e. how many pupils attended a rural school and how many pupils attended an urban school. Based on this division, 219 students from urban schools and 127 students from rural schools solved the test with the given task.

Statistical processing was carried out within NIVAM (National Institute of Education and Youth). During the evaluation of the task, it was found that the gender and the location of the school did not statistically significantly influence the solution of the task itself.

As we already mentioned in the methodology, we determined the unsolvedness, difficulty, sensitivity and success of mathematical problems.

Unsolved task means how many pupils did not even try to solve the task. In our case, it was less than 5% of all pupils, which means that only 17 pupils did not even try to solve the given task. Based on these data, we can conclude that the task was attractive enough for the students. Failure to solve the task in general can also affect its order in the test. This task was in 13th place out of 30 tasks, from which we can conclude that its position does not need to be changed.

Difficulty is a complex data from a didactic point of view, the structure of which is conditioned by the structure of the teaching material and the requirements for logical-recognition operations when assigning tasks. The intended difficulty of the test must be based on the properties of the components that make up the learning material and on the task itself:

1. degree of importance of the learning element in the curriculum structure,
2. difficulty and age appropriateness, logical-cognitive operation,
3. complexity of the required intellectual and manipulative skills.

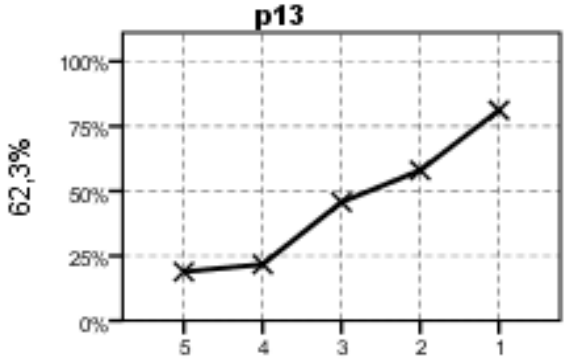
The difficulty index can have a value from 0 to 100 %. The more pupils solve the problem correctly, the higher the percentage. Easier tasks have a higher difficulty index. (Kubiš, 2015).

In the statistical processing of the individual tasks of the test, the task created by us received approximately 45%, which means that it was a moderately difficult task. This level may mean that the third graders have some difficulty in identifying data according to the given criteria, as it requires linking reading comprehension skills and chart orientation.

The sensitivity of the test expresses the extent to which the test can distinguish between students with good and poor knowledge (discriminative power of the test): it is especially important for NR tests (discriminatory). Here, task piloting is essential, after which each task is analysed separately. It is necessary to determine the distinguishing value of the tasks, that is, the sensitivity. The high sensitivity test contains tasks of different difficulty (easy, medium, hard). Sensitivity refers to the ability of a test to distinguish between students with different levels of actual knowledge and skill. In a sensitive test, students' results should be adequately distributed across the entire point scale. The test is not sensitive if all pupils achieve an excellent or poor result in the test - it does not differentiate between pupils (Kubiš, 2015).

The statistical evaluation of the task is shown in Graph 1 and subsequent Table 4.

Graph 1. Sensitivity of the Task with Respect to Performance Groups



It can be seen from the Graph 1 that the success of solving the task with the performance group is increasing. This means that students with a higher level of knowledge achieved better results in solving the given task than students with a lower level of knowledge. The performance group is divided on Graph 1 according to the assessment that the tested students achieved in mathematics. Table 4 is also related to Graph 1.

Table 4. Sensitivity of the Task with Respect to Performance Groups

	Percentile Group of number				
	PG1	PG2	PG3	PG4	PG5
p13	81,2	58,0	45,7	21,7	18,8

From Table 4, we can see that more than 81% of pupils - excellent mark (PG1) were successful in solving the given task, i.e. they solved the task correctly. As the evaluation worsens, the percentage of successful solvers also decreases. So, for example, in performance group 3 (VS3) - mark good, there were only less than 46% of successful solvers.

Graph 1 and Table 4 show that this task differentiates pupils well according to their performance. Therefore, it can be used without change as a task for other tests.

The 2nd presented mathematical problem was from 2nd test. This test was solved by 340 pupils from 39 schools throughout Slovakia. Of the total number of pupils, there were 163 boys and 177 girls, 217 pupils from urban schools and 123 pupils from rural schools solved the test with the given task.

Table 5. Characteristics of the Task Toys

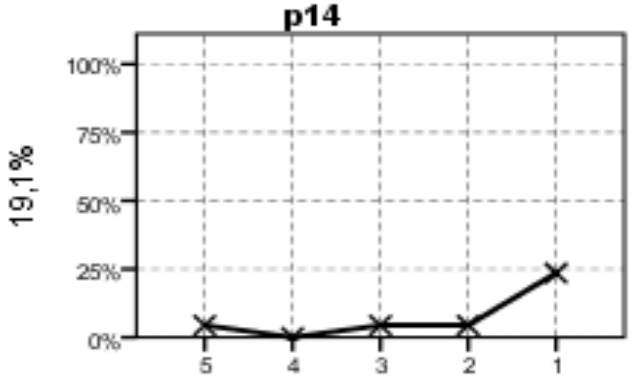
Toys	
Level:	1st cycle
Performance standard	The number of possibilities to pay the amount
Type of task	open
Theoretical framework	
Range of requirements: R3– connection of several areas of mathematics. Mathematical competences C2 – understand content and apply calculation, analyze options. S2 – connect, find connections in the data, choose, and use the representation of mathematical objects. M2 – recognize a model that is not common to students, interpret the results.	
Task's characteristic: When solving the task, knowledge from several areas is needed: the solution of simple combinatorial situations and numbers and variables. The pupils are expected to find and connect data from text and image. It requires a basic understanding in a real context. The problem is aimed at adding two or three natural numbers with and without a transition to 20 from memory. It requires a basic understanding in a real context. The expected solution from the student is to list all the possibilities of one, two or three numbers, the sum of which is less than 20. The expected solution is finding the number of possibilities.	

In the assignment there are pictures of four toys with prices – 18€, 9€, 8€, and 3€. Girl has 20€. The question is: How many of all options did she have to buy at least two toys?

This problem was for pupils very difficult. In the statistical processing of the test tasks, this task received only about 7%.

This task was in 14th place out of 30 tasks. Unsolved of this problem was higher, 12%. Based on these data, we can conclude that the task was less attractive for the pupils. We assume it has something to do with combinatorics. Third - graders in Slovakia have almost no experience with this area, despite it being part of the curriculum. The most common incorrect answer was: 3 options. We assume that the pupils forgot the possibility to buy three toys at the price of 9€, 8€, and 3€. Graph 2 shows sensitivity of the task with respect to performance groups.

Graph 2. Sensitivity of the Task with Respect to Performance Groups



Unlike the first task, this one does not differentiate well. As can be seen from the graph, almost all income groups achieved low success rates. Table 6 shows that in the highest performance group the success of the solution was only 25%.

Table 6. Sensitivity of the Task with Respect to Performance Groups

	Percentile Group of number				
	PG1	PG2	PG3	PG4	PG5
p14	23.5	4.4	4.4	0.0	4.4

A task with such parameters cannot be included in the test. Therefore, we decided to change its assignment in the second pilot testing. New question is: How many different pairs of toys can she buy if she has 20€?

We expect that changing the word "options" to the word "pairs" will increase the success of the solution, as well as the sensitivity and reduce the unsolved. We also simplified the task by using the word pairs, as we omitted the possibility of buying three toys. The new wording of the task will be piloted in 2024.

When evaluating two selected tasks as part of pilot testing, we focused on their difficulty, sensitivity, success and, finally, their unsolved. Statistical evaluation of individual tasks was done through IRT. Based on this processing, we found out what the parameters of the test tasks are. Tasks with good parameters were moved to further pilot testing without changes, and tasks with insufficient parameters were changed based on the analysis. We will pilot test the changed tasks again to find out if they have improved their parameters.

Of course, it is not enough to change only the testing, it is also necessary to change the training of students, but also of future teachers. They must be ready to independently create mathematical problems for their students and thus develop

their mathematical literacy and critical thinking. However, it is necessary to avoid the fact that teachers do not focus only on preparation for testing, but above all on the comprehensive development of students. (Göloğlu & Kaplan, 2021).

Mathematical tasks influence the teaching and learning character of learners. The nature of student learning is determined in two ways, among others:

1. the type of task,
2. the way it is used (Clarke & Roche, 2010)

Research shows that the structure of lessons and the types of tasks used in mathematics lessons are different around the world (Bangtho et al., 2015). In most European countries, teachers focus on skill development, with students focusing on practicing routines, rules, and patterns, while in Japan, teachers focus on developing conceptual understanding, spending as much time solving challenging problems as practicing skills (Stigler&Hiebert, 1999, Phu-Udon, 2001). Japanese students have a creative way of solving mathematical problems, they invent and present new methods of solving mathematical problems (Shimizu et al., 2010). This may also be one of the reasons why Japanese students achieve above-average results in PISA testing.

Conclusion

Criterion tests are designed to determine whether a pupil has a set of skills, competencies, or knowledge. Their goal is not to compare the pupil with other pupils of the same age. Test makers analyse components of specific academic skills, such as number comprehension and then write test items that measure whether the child has all components of the skill. The tests are standardized in terms of the level of skills a child should have. Nevertheless, the tests are constructed to measure how a child is acquiring specific skills (Berger, 2013, Webster, 2021).

According to (Webster, 2021) criterion math test should reflect the range and sequence of state standards (such as the common core national standards). It reflects the skills needed at any age: for young pupils, understanding one-to-one correspondence, counting and at least addition as an operation. As the child grows, he is expected to acquire new skills in an appropriate sequence that builds on earlier levels of skill acquisition (numerical operations with natural numbers; relations, functions, tables, and diagrams; geometry and measurement; combinatorics, probability, statistics; logic, reasoning, evidence). A criterion math test should reflect the range and sequence of state standards (such as the common core national standards). It reflects the skills needed at any age: for young pupils, understanding one-to-one correspondence, counting and at least addition as an operation. As the child grows, he is expected to acquire new skills in an appropriate sequence that builds on earlier levels of skill acquisition (numerical operations with natural numbers; relations, functions, tables, and diagrams; geometry and measurement; combinatorics, probability, statistics; logic, reasoning, evidence).

According to (Kantorov, 2000) it is not appropriate to use only one method of evaluating the performance of a pupil (and thus also of a teacher, class, school) on a national scale. school principals, teachers, parents, and students should learn as much as possible about the tests used to assess mathematics achievement.

The more we know about what is on the national tests that students are required to take and how those tests are scored, the better you can determine the meaning and usefulness of the results. Criterion testing in Slovakia is only in the beginning. Nationwide testing in 3 cycles of mathematics (after the 3rd, 5th and 8th grade of elementary school) is planned from 2026. Until then, pilot testing will take place in these grades of elementary school. These will provide test makers with feedback on tasks as well as entire tests.

The teaching of mathematics and especially its content has been reduced over time not only in Slovakia, but the prevailing opinion is also that creating high-quality mathematical tasks is simple and straightforward. We consider this assumption to be erroneous. Mathematics is required for accurate reasoning, and errors easily creep into the words, numbers, and symbols that express assessment tasks (National Research Council, 1993).

The created methodology represents an imaginary "starting line" that will allow, through the gradual automation of individual processes over time, to implement this tool in the environment of educational reality within the framework of planned innovations in the field of evaluation of educational results following the curricular reform implemented from the Recovery and Resilience Plan. The introduction of criterion-referenced testing in schools will provide another dimension of viewing the pupil's performance, which should primarily serve for the individual assessment of the pupil's performance within the tested content and the possibility to clearly identify his strengths and weaknesses. Test tasks linked to learning outcomes in mathematical literacy could eventually be incorporated into the new curriculum as Shepard, Daro & Stancavage (2013) states. The results of several research show that the mathematical literacy of elementary school pupils is still insufficient. As the authors state, this may also be due to a limited number of problems based on mathematical literacy. These researchers also state that research analysing mathematical literacy also requires a higher level of critical thinking (Rachman & Amir, 2022, Little et all., 2020, Little et al., 2022). Criterion tests mainly contain mathematical problems based on real life, and therefore it is necessary to pay attention to the process of their creation. Based on the results of several research, each student has a different level of literacy. That is why tasks in criterion tests must be created in such a way that this level can be identified and defined (Nurutami et al., 2018).

Creating mathematical problems should be part of teaching (Lieberman, 2018). For some students and teachers, it is difficult to find several correct solutions to the task (Roth & Ames, 2014). Finding different solutions to open mathematical problems helps to develop creativity not only among students but also among teachers. Through the development of creativity, students' relationship to mathematics can also be improved (Švecová & Pavlovičová, 2012, Švecová et al., 2014). If we want to focus on the development of critical thinking and mathematical literacy of primary school pupils, it is necessary to develop these

components in teachers of the primary level of education as well. Papanikos (2023) also draws attention to the need to focus on the education and evaluation of future teachers at the primary level of education

Acknowledgements

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The Experience of Mentoring Students Online: An Evaluation of the Transition from Face-to-face to Online peer mentoring

*By Chara Gkioka**

Peer mentoring has long been employed as a method of facilitating the learning process with peer mentors or learning facilitators as also described in this paper, serving as an alternative to faculty teachers. However, there is dearth of qualitative studies exploring the experiences of learning facilitators teaching or mentoring (the two terms will be used interchangeably) in an online environment. The aim of this study is to examine how undergraduate students at the largest college in Greece experienced and evaluated their roles as learning facilitators and to what extent their role was hindered or enhanced in a virtual setting. I conducted semi-structured interviews with learning facilitators who have experienced both online and face-to-face peer mentoring. Upon the transcription of the interviews verbatim, I performed qualitative thematic analysis. The results revealed that all peer mentors prefer face-to-face mentoring to e-mentoring and unanimously believe that online mentoring cannot replicate the practices of face-to-face peer mentoring.

Keywords: mentoring, online, higher education, impact

Introduction

Although the popularity of peer mentoring has increased in higher education in the United Kingdom, good quality, evaluative research on peer mentoring remains scarce (Collings et al. 2014). The findings of the bulk of research focus on the positive effects peer mentoring exerts on academic achievement and retention (Drew et al. 2000; Budney et al. 2006; Crisp 2010). However, the growth of mentoring programmes in a technology-mediated environment and their potential to raise student engagement warrant further research on processes and the factors enabling or even constraining successful online mentoring. This study aims to contribute to existing research on the effects of peer mentoring by studying such effects in the underexplored area of online peer mentoring. In particular, this study has shed light on online peer mentoring with a specific focus on the mentor's perspective and experience. While the mentor's perspective is more likely to be overlooked with emphasis being placed on the mentee's perspective and how the latter would evaluate the method, it is worth examining the mentor's perspective while delivering their mentoring online. That is to say that the feelings of the service provider need to be examined prior to examining the service itself. The purpose of this paper is to examine

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the effects of technological mediation on the mentoring process such as on mentor-mentee relationships and learning. In other words, the paper seeks to shed light on the effectiveness of online peer mentoring compared to face-to-face peer mentoring. As Zuhari et al. (2019) concluded, further research is worth conducting, specifically in the area of student support provided online, in line with the changing needs of students and recent advances in new technology. The objective of this paper is to illuminate the contributing factors for successful online peer mentoring and help us gain insight into the kind of support that is necessary for mentors in order to engage in effective online peer mentoring relationships. Therefore, the study has been carried out as a qualitative study with the following underlying questions:

1) What factors enable successful online peer mentoring?
2) What factors constrain successful online peer mentoring?

First, the key components of effective mentoring relationships are presented. Then, the way in which a virtual environment impacts peer mentoring is examined. Finally, factors that could moderate the effects of technological mediation on interaction with the student are discussed. It was found that online peer mentoring cannot replicate face-to-face mentoring; possible reasons are examined and discussed.

Literature Review

Defining Peer Mentoring

One of the main challenges regarding the definition of peer mentoring is the fact that across the literature there are various terminologies used to describe mentoring such as guiding, tutoring and assisted learning (Kram 1985; Topping 1996; Dioso-Henson 2012). As a result of this wide-ranging terminology, the terms are frequently mixed-up or used interchangeably. Making things clearer, Collier (2017) differentiates between *hierarchical mentoring* and *peer mentoring*. *Hierarchical mentoring* occurs when two people from two different social positions such as a counselor and student or an academic advisor and student or even a faculty member and student are involved, whereas *peer mentoring*, which is the focus of this paper, is described as a relationship involving a more experienced student providing assistance, knowledge and advice to a less experienced student. Shifting away from hierarchical mentoring, which I myself practise as an academic advisor, my aim is to examine the strengths and weaknesses of peer mentoring which take place not in the typical face-to-face form, but in an online environment which became the norm in the COVID-era and might continue in the high-tech modern era. Since the environment in which a service takes place is of paramount importance, the concept of the mentoring environment is analysed next.

The Mentoring Environment

Davis and Nakamura (2010, p. 1060) characterise the mentoring environment as a *"function of a relationship that rests upon a set of interactional foundations that allow a protégé to capitalize on the strengths of the mentor thus facilitating behaviours that will enable the protégé to develop and internalize the requisite knowledge, skills, and attitudes (KSAs) as fully as possible".* However, Sng's et al. (2017) description of the impact the role of the mentor and the host organization can exert on the mentoring relationships has challenged its applicability in the modern practice of mentoring. Given the dearth of studies on mentoring environments, Kalen, Ponzer and Silen (2012) argue that learning environments could be used to provide understanding of mentoring environments. To clarify, the learning environment structure consists of five sub-themes including the host organisation, the formal curriculum, the tutor, the learner and the relationship between them (Hee et al., 2019), which is the focus of this study and specifically how this is experienced in an online setting. Accordingly, a collaborative relationship based on mutual *commitment*, *cooperation* and *authenticity* fosters the relationship between the tutor and the learner, enhancing the creation of personalised ties while preventing the isolation of the learner (Hee et al., 2019). Extrapolating learning environment data to the mentoring environment setting is possible considering the commonalities in both settings and as a result mentoring environments can be defined as *"shaped by the nature, culture and structure of evolving mentoring relationships between the mentor, the mentee, the host organization and the curriculum (henceforth quartet of stakeholders). Mentoring environments evolve to support and nurture mentoring relationships in dynamic conditions and as particular relationships amongst the quartet of stakeholders change."* (Hee et al., 2019, p.2196). The key components of effective mentor-mentee relationships in this quartet are analysed next.

The Key Components of Effective Mentoring Relationships

Researchers on youth mentoring define the quality of mentoring relationships as based on the *frequency of contact* between the mentor and the mentee, *emotional closeness* and *durability* of the relationship (DuBuois et al. 2011). Rhodes et al. (2005) also acknowledge mentor-mentee *closeness* and *empathy* as two crucial contributing factors to high quality mentoring relationships.

Emotional Closeness

As Latino and Unite (2012) argue, students can share concerns with their peer educators more freely than with their professors as the former can be less intimidating. Supplemental Instruction as mentioned in their study fosters a nonthreatening environment since learning is facilitated by peers. As a result, the approachability of peers can be crucial for first-year students who may feel home-sick and find it difficult to develop a sense of belonging. Indeed, a mentor who has already experienced or currently faces similar challenges is in a better position to relate to their coevals. As Griffin and Romm (2008) pinpoint, peer educators can bridge the gap between the

faculty and the student body, guide students to campus resources and constitute role models for academic and co-curricular behaviours.

Empathy

Student tutors and student learners having similar social roles are thought to be *socially congruent* (Schmidt, 1995). In other words, interpersonal qualities shared between mentors and mentees not only enhance informal and empathic communication, but also establish a learning environment which promotes an open exchange of students' personal concerns and ideas. Equally important is the role of *cognitive congruence* according to which student tutors and student learners have similar learning experiences and a similar knowledge base and are therefore considered to be on the same 'wavelength' (Bugaj, 2019). Indeed, the lack of knowledge and expertise of mentors, compared to more experienced faculty members could be offset by *cognitive congruence* (Dolmans et al, 2002; Groves et.al. 2005). The concepts of *social* and *cognitive congruence* are further analysed next.

Social and Cognitive Congruence

Research on the relationships created throughout peer mentoring in educational contexts highlight that effective mentors can respond to mentees' academic and psychosocial requests as well (Ward et al., 2014). Such levels of response postulate social and cognitive congruence (Ten Cate and Durning, 2007). Social congruence can be enhanced when mentors disclose information regarding their own learning experiences and reveal their own past or even present learning challenges (DuBuois et al. 2011). In turn, mentees are then more likely to disclose their own learning gaps thus enabling support from their mentors. Equally important to social congruence is cognitive congruence which is defined as the ability of mentors to understand the cognitive and learning challenges of their mentees as well as anticipate any learning difficulties (Melgar and Meyers, 2020). When this is coupled with social congruence, mentees feel that the difficulties they face in the learning process are not only realised by mentors, but also addressed through explanations suitable for their learning needs (Melgar and Meyers, 2020). Social congruence has to be established prior to the mentors' use of cognitive congruence to provide academic support. In other words, the establishment of a strong emotional connection is necessary before mentors proceed with the achievement of the objectives of the programme or the academic support of the student. The extent to which social and cognitive congruence can be achieved in the online environment will be discussed, but first it is worth comparing online with face-to-face mentoring.

Online vs Face-to-face Peer Mentoring

The onset of the pandemic has proven that peer mentoring can take place in a technology-mediated environment, replacing the common in person-experience with online mentoring. Online mentoring can be both synchronous, with the use of video and audio-conferencing tools, and asynchronous using text-based media

(Schwartzman, 2013). Mentors, however, are faced with the challenge of maintaining student-centredness and engagement while providing their services online. Although the implementation of programmes that render peers as leaders in the academic domain continue to rise (Keup and Mullins, 2010), there has been scant research on whether these programmes could be successful in an online setting. As Melgar and Meyers (2020) highlight, in spite of the growing significance of online mentoring, studies on particular mentoring dynamics remain scarce. However, focusing on existing research on online mentoring, they argue that the online communication environment offers various advantages to participants in comparison to face-to-face mentoring programmes. Specifically, online mentoring can render all participants equal as demographic characteristics can affect interactions less (Scogin and Stuessy, 2015). Consequently, interactions between mentors and mentees are based on common goals and interests rather than on perceived differences or similarities stemming from demographic factors. Using online technologies may also be seen as less intimidating than interacting face-to-face by some online mentoring participants (Scogin, 2016). Hizer et al. (2017), in their study regarding the effectiveness of online supplemental instruction found that the outcomes of students taking part in online sessions were equivalent to those participating in face-to-face ones, a fact suggesting that the online environment was not an impediment to the effectiveness of the programme.

A number of challenges regarding online mentoring programs do exist however, mainly related to engagement and whether this can be sustained via online communication platforms, especially when the mentor-mentee interaction is exclusively online (Melgar and Meyers, 2020). Decreased engagement can result from the lack of real time interaction, especially if contact between mentors and mentees is not frequent and timely. However, web-conferencing, among other synchronous communication tools, target to address the shortcomings of asynchronous tools since participants can employ useful verbal information, such as words and tone of voice, and non-verbal information while interacting in the mentoring session (Melgar and Meyers, 2020). On the other hand, Shpigelman and Gill (2013) argue that limited digital literacy skills on the part of participants can affect online interactions and impact not only the motivation of participants to engage, but also the frequency of the mentor-mentee communication. Scogin and Stuessy (2015) in their study of online mentoring found that, despite the motivational support provided to mentors, there were variations in terms of the type and amount of support provided. They attributed these variations to challenges related to communication in an online environment and therefore recommendations were made for further training for online mentors. Shpigelman and Gill (2013) concluded that a more formal and distant communication style used by mentors in their interaction with mentees was conducive to unsuccessful online mentoring relationships. The authors also found that high levels of uncertainty in terms of which was the best way to use an online format led to unsuccessful interactions and, as a result, they recommend that online mentoring should function around specific discussion topics. Successful mentors, on the other hand, asked their mentees direct questions, employed a conversational style and offered them further learning resources (Scogin, 2016). Studies pertinent to the effectiveness of synchronous communication tools provide mixed results. Beaumont et al. (2012) in

their study of peer assisted programs found that a sense of connection between the mentor and mentee was low although communication took place through video conferencing and audio. Similarly, Hizer et al. (2017) in their research on the effectiveness of peer-led sessions at university in which both synchronous and asynchronous communication tools were used found that students opted for chat-based interactions instead of real time mentoring sessions. Overall, research on online peer mentoring programmes is an area that needs to be further developed with researchers calling specifically for further research on the effectiveness of synchronous communication tools in peer mentoring and to what extent they can replicate the face-to-face experience. The purpose of this paper as explained next is to contribute to this direction.

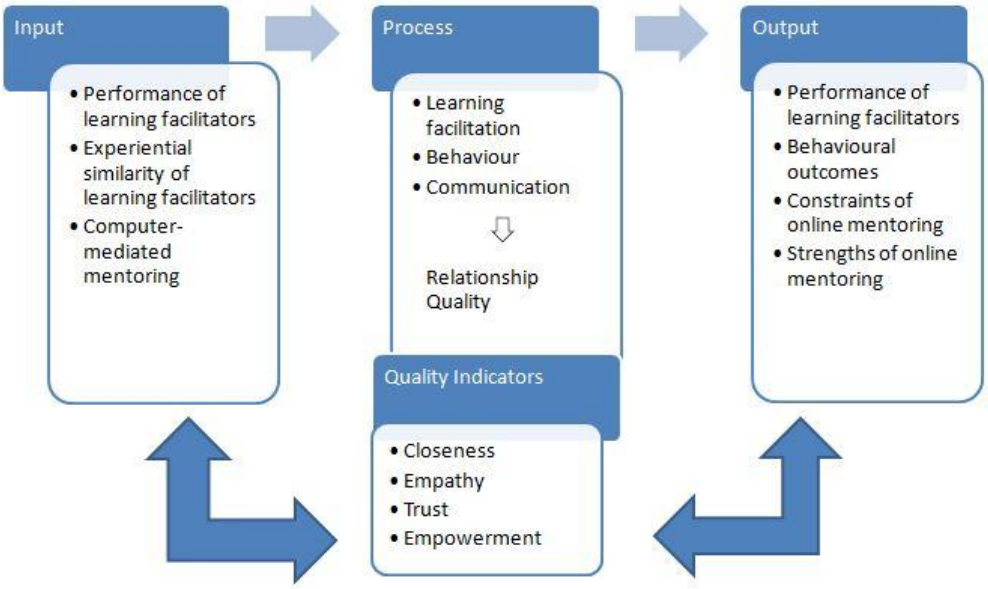
Methods

Research Design

This study provides a process evaluation with the intention of aiding the decision-making process when a review takes place. Since the objective of evaluators is to aid decision makers make wiser decisions, evidence is provided which shows both the successes and drawbacks of programmes. As a result, evaluators pinpoint some of the factors involved with better or worse outcomes, as well as explain how the programme works in practice. There are expectations, then, that these data will influence the decision-making process and affect the actions that managerial staff takes (Weiss, 2005). To gain full understanding of mentoring, evaluation measures should ideally address the mentoring process and the outcomes as well as the factors that could shape it (National Academies of Sciences, Engineering and Medicine, 2019).

The conceptual framework in order to evaluate the transition from face-to-face peer mentoring to online peer mentoring and its effect on mentors' feelings and experiences was a general input-process-output one as illustrated in Figure 2. The model was based on Input-process-output model of mentoring adapted by Eby et. al (2013) and National Academies of Sciences, Engineering, and Medicine (2019) and was further adapted to serve the purpose of this research.

Figure 1. Input-process-output Model of Mentoring adapted by Eby et al. (2013) and National Academies of Sciences, Engineering, and Medicine (2019)



Context of the Study

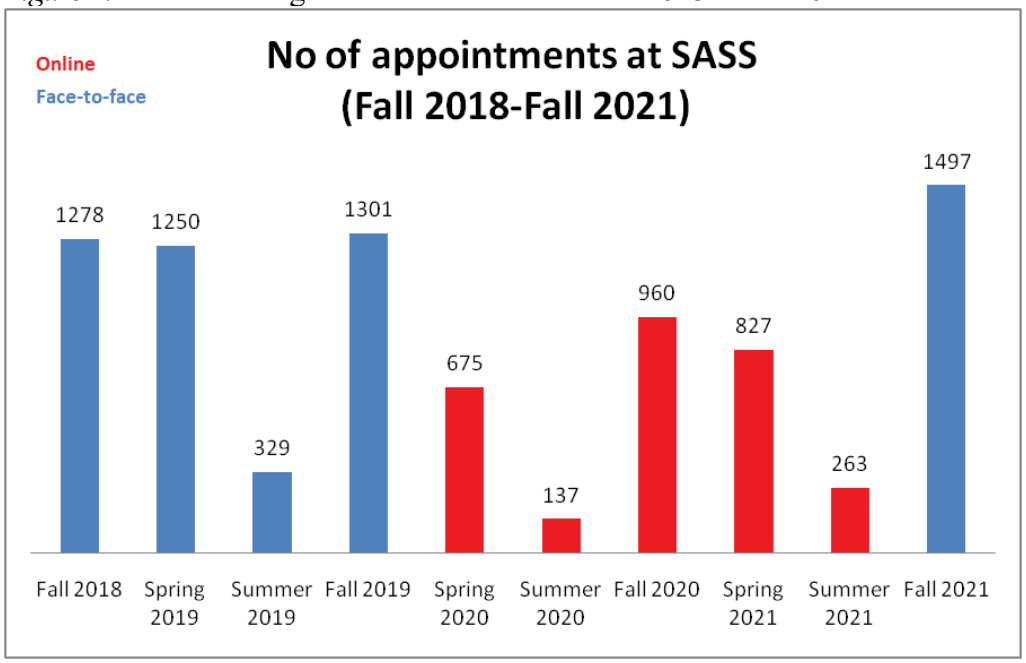
This study was conducted in the largest private college in Greece, Deree College, which, as reported in its website (www.acg.edu) serves almost 4200 students in a variety of fields. Student Academic Support Services (SASS) is presented as a key benefit of the College since this service is not offered by other private colleges, let alone public universities. The role of SASS, which is also shared on the site of the college (https://www.acg.edu/undergraduate/academic-enrichment-programs/student-academic-support-services/the-role-of-sass/), is to enhance the educational experience through both one-to-one and group sessions. The philosophy of learning facilitators at SASS is non-instructional reflecting their own mindset, critical reasoning skills and abilities. Their role is supportive and distinct from that of instructors as the learning facilitators are not content experts or evaluators. However, instructors and learning facilitators collaborate and through their cooperation aim to assist students with developing appropriate college skills to become owners of their own learning process.

Impact of COVID-19 on Peer Mentoring at Deree College

Mentoring students face-to-face was abruptly overturned at Deree College during the Spring Semester 2020 due to the COVID-19 pandemic. While in the Fall Semester of 2019, 1301 students received learning facilitation on campus, a number similar to that of the previous year (see Figure 3), in the Spring Semester, with the onset of the pandemic and the closure of the college on March 3rd and with the learning facilitation turning online, the number plunged to almost half. It is worth noting that although the figure for Spring Semester 2020 refers to online mentoring, few sessions took place face-to-face in January and February 2020. After March and until all learning facilitators returned to campus in September 2021, mentoring sessions were conducted

via Zoom meetings and MS Teams. Remote mentoring continued in Spring and Summer 2021, with 827 and 263 students being mentored mainly via MS Teams respectively.

Figure 2. Peer Mentoring Sessions at SASS from Fall 2018 to Fall 2021



Data Sample

Participants in this research are the learning facilitators of SASS who are directly involved in the delivery of mentoring to other students, regardless of the programme attended at Deree College. Learning facilitators serve as an academic resource to students by helping them understand and apply course content; they support the development of essential academic skills by offering their guidance to students to reach their academic goals. As a result, learning facilitators help students identify their needs in the context of specific tasks and propose processes and methods appropriate to the course level and assignment. The SASS learning facilitators perform their duties in direct or indirect cooperation with Deree instructors, bearing in mind the ultimate purpose, which is to help students improve. To that end, the minimum requirements for the Selection of Learning Facilitators are their very good academic standing, a minimum C.I. of 3.5 out of 4, and their completion of at least 50 out of the 121 credits at the college. In addition, all learning facilitators belong to at least one "Circle of Learning", which is determined by the facilitator's major field of study, corresponding to the following "Circles":

- Quantitative courses, Natural Science, Computer Science
- Business fields
- Social Sciences
- Humanities
- Performing & Visual Arts

The intention of the study was for all circles to be focused on, so that the sample is qualitatively representative and a holistic perspective is achieved. The aim is accomplished as shown in Table 1 below. I subjected data from male and female participants, albeit using pseudonyms, so that similarities and differences could be identified.

Table 1. Circles taught by each Participant

Participants		**Giannis**	**Maria**	**Giorgos**	**Pavlos**	**Ioanna**	**Vasilis**	**Tina**	**Rita**
CIRCLES	**Quantitative courses, Natural Science, Computer Science**			√	√	√	√		√
	Business fields	√		√			√		√
	Social Sciences	√	√		√	√		√	
	Humanities		√		√			√	
	Performing & Visual Arts		√		√				

The Office of SASS at Deree College consists of the Director of the Student Academic Support Services, the Secretariat and 21 learning facilitators. The intention was that 8 learning facilitators, more than 1/3 of the overall group, be interviewed to ensure saturation. In the event that saturation was reached within 5 interviews, (one participant from at least one Circle), it would still be necessary to extend the interviews to 8, if not more, to ensure a holistic perspective of SASS regarding the topic to be researched. However, in the event that saturation was not reached within 8 interviews, the number of the participants would be extended as needed.

Participants whose studies were from different circles were selected from the total of 21 Learning Facilitators at Deree College to ensure that the sample is qualitatively representative. All participants were audio recorded after signing a consent form. The interview consisted of 6 open-ended questions which, eliciting oral data, focus on the mentors' experience of interacting and teaching online. In addition, prompt questions were also posed throughout the interview in order to elicit as much information as possible, depending on the flow of the interview, and to foster the environment of a casual conversation, rather than a strict interview

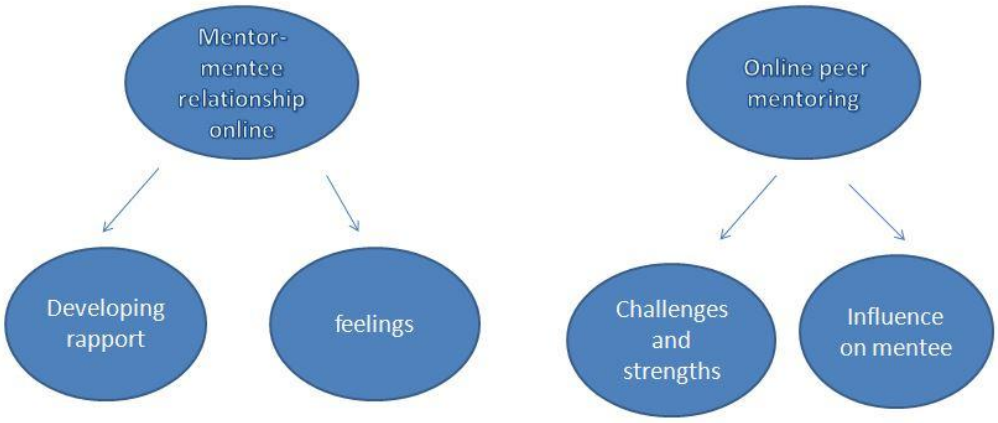
process. The main themes covered were: 1) the experience of the interviewees with the change to online mentoring and the feelings derived from such a change, 2) the main challenges they faced and how they would evaluate such a change, 3) how they would assess the impact of such a change on mentees 4) which are the best practices to adopt and action to be taken by both SASS and universities to enhance the online mentoring experience.

All interviews were conducted face-to-face and were audio recorded. The verbal data were transcribed into written form so as to conduct a thematic analysis. It is worth mentioning that in my effort to conduct an effective thematic analysis the transcripts retained all the necessary information while remaining true to their original nature (Edwards, 1993).

Interview Analysis

Analysis focused on the area of interest, that is, how learning facilitators experienced their role after abruptly having to mentor peer students online and the equivalent thematic codes. In the following section, taking into consideration online peer mentoring and the implications based on the quality indicators of mentor/ mentee relationship mentioned in the literature review, I will analyse the experience of the learning facilitators interviewed. Overall, the thematic analysis that follows is inductive, being data-driven and not fitting into a pre-existing coding frame or any analytic prejudices of the researcher (Braun and Clarke, 2006). Thematic analysis was used due to its flexibility and opportunity to provide a rich and detailed account (Braun and Clarke, 2006). A theoretical approach which required my engagement with the literature prior to analysis was used (Braun and Clarke, 2006). By examining the interviewees' experiences of mentoring students online as learning facilitators, I investigated how their own feelings mirror the challenges of online mentoring mentioned above. Interview excerpts presented in this paper provide the basis for my research findings while rendering the concepts understandable and applicable. It should be noted that learning facilitators were asked to share their feelings of mentoring students online based on their experiences rather than which they perceive to be the differences between online and face-to-face mentoring. What is more, the interviews include examples of the mentors' experiences illustrating this comparison. Based on Braun and Clarke's (2021) step by step guide of doing thematic analysis, I firstly familiarised myself with data (phase one), then did coding (phase two) and generated initial themes (phase three) which I developed and reviewed next (phase four). My final themes and sub-themes, after refining, defining and naming them (phase five) are the following:

Figure 3. Map showing Two Main Themes derived from Interviews and Sub-themes



I am aware that the coding I have undertaken helped me retain an empathetic awareness of the experiences described by the participants. This enabled me to engage in theoretical analysis of the discourse without losing connection to the affective quality of their accounts. In the last phase (phase 6) I began writing up the analysis presented next.

Results and Discussion

Based on the research questions and within the theme of mentoring relationships online and its subthemes, the main points that emerged were feelings of impersonalisation and lack of intimacy primarily because mentors often did not have eye contact with the student and could not see their facial expressions as in many cases students opted for a turned off camera.

Feelings of Impersonalisation and Lack of Intimacy

Seeking assistance from learning facilitators at a distance can be achieved in a variety of ways, with video conferencing being the most preferred method. Unlike face-to-face mentoring sessions, online mentoring may lack the visual cues, including body language and eye contact that help students and mentors develop a positive relationship; this occurs when the mentee opts for a turned off camera. As a result, the mentor, being unable to see the mentee's face, must infer from the tone of voice what the student's concerns are. It is clear that all participants expressed their concern that online mentoring posed hindrances for mentors in terms of comprehending whether or not the mentees fully understood what was being conveyed to them due to the absence of non-verbal cues. It was also stated that interpreting mentees' feelings and insecurities was not as straightforward with online mentoring. Since full communication involves understanding both verbal and non-verbal cues, there was consensus that online communication posed challenges. Both Giannis and Maria

mentioned the lack of intimacy experienced as opposed to face-to-face mentoring sessions. Specifically, Giannis mentioned:

> *"It was quite difficult because most people wouldn't turn on their cameras. So, it was like talking to the wall, I wasn't sure if they listened. They pretty much stayed in the call until I was done talking which was kind of puzzling […] I think that you get a lot from the other person's facial expressions. […] So, it was like we were completely detached with one another. There was a wall between us."*

Maria added her concern about impersonalisation rendered due to the lack of eye-contact stating:

> *"It wasn't the same as doing it in person because there are many things that influence the face to face session and the online. One of the more important aspects of the face to face and facilitation in general is the connection you can have with the student […] especially for a student having dyslexia or something like that, there's a need to have the presence there […] I need to see the body, I need to know that they see me in order for them to be focused."*

Similarly, Giorgos, Pavlos, Ioanna and Vasilis presented the scarcity of facial expressions and body language as a great impediment to learning and mentoring. Characteristically, Ioanna stated: *"[...] the interaction is so different. Here I can see their facial expressions, I can see their body language […] with online especially many times they wouldn't even open their cameras. I need to have a face to go with a name. And I was essentially talking to a blank screen quite a few times".*

Rita mentioned: *"[…]some students were not opening their cameras, so I had to ask because it was like talking to the wall. And I didn't know if they were understanding what I was saying or not. So, I was asking them turn on their cameras, because it's better, you can teach better, you can see if they're confused, or not […] face to face is better because you have like connection with the student […] what I'm doing is like sitting next to them, so I can understand when they're confused, where to stop."*

These statements shed light on how online mentoring instigates alienation and how the participants felt disconnected from their mentees. However, the difficulties present in virtual interaction with the students may hinder not only communication, but also the establishment of rapport with the mentee. Pavlos mentioned, *"[…] when people come here, you kind of build a connection. Because some people feel like they're too close with you or friends with you. […] It's kind of weird, but it's better because I believe it builds a better connection and better relationship even if you're not friends. […] I think the main difference is the relationship you can build through face to face and not with online classes."*

A similar concern was expressed by Vasilis who stressed the need for cooperation, empathy and closeness with the mentee while building a relationship in which mentor and mentee are equals. Specifically, Vasilis mentioned, *"I think that empathy is important […] I think that there needs to be cooperation between the student taking the course and the learning facilitator. They have to work together to come as close as possible, […] try to get to know each other a bit. Build a*

relationship, that it's not necessarily the one of a teacher student, because in the end, we are not teachers, we are just humans that have passed the course. This is something that the students need to understand. We were in the same position.". This approach can indeed foster not only engagement in learning (*cognitive congruence*), but also psychosocial support (*social congruence*). Giannis also highlighted that empathizing with the mentee in person greatly differentiates face-to-face mentoring from e-mentoring. In his own words *"(mentees) need to know that we're just like them […] we struggle as well."*.

Since interaction mediated by technology could impede the establishment of a relationship or rapport (Driskel et al, 2003), the need for the creation of such intimacy while interacting with the student online is of paramount importance. As Giorgos suggested it is vital for the mentee to concentrate and be able to communicate fully with their mentor. To ensure concentration, it is advisable for the mentee to feel that they have entered the learning space of the mentor, thus drawing the attention of the mentee. However, the online environment posed challenges to all the participants.

Challenges and Strengths of Online Peer Mentoring

One of the main challenges all participants faced was the difficulty in replicating the best practices of face-to-face peer mentoring. The majority of the participants found online peer mentoring time-consuming and their job restricted. Characteristically, Tina argued:

> "*I felt like a job being done as 20% instead of potentially 100%. The students, including myself, are in a completely different context. Because since we are in our own rooms, there are a lot of familiar distractions, a lot of things that you kind of feel like that you wanna devote your time to them instead of what's happening right in front of you."*

Similarly, Ioanna, teaching Natural Science and Math courses, highlighted "*we covered half the material that we would have if we were face-to-face".* It is worth quoting Ioanna's challenge while teaching Biology:

> *"How on earth am I supposed to teach someone photosynthesis, if I can't actually draw something and show him a flower to start with. It was very, very hard to convey the information that was needed in a way that made students understand what the topic, the material was about. Now, MS Teams does have a whiteboard but with the cursor, trying to draw it was really bad writing and time-consuming".* It is worth noting however, that this time-consumption derived from low computer literacy skills or even lack of equipment on the part of mentees. Specifically, Pavlos stated that " *(mentees) don't know how to check, they don't know how to use the code, they don't know basic stuff, which makes it very difficult. […]And there are many difficulties with equipment. Some of them don't have computer, some of them don't have Wi-Fi connection.".*

It must be stressed that there was consensus among learning facilitators and especially for those teaching Natural Science courses and quantitative courses that the online environment cannot replicate the practices of face-to-face peer mentoring. This became more evident to certain learning facilitators who dealt with students having

dyslexia or other learning difficulties. The experience of Giorgos who has dyslexia himself is worth considering*: "For me, because I have dyslexia […] it was very hard to focus. So, this was a problem for my online class. I imagine students that also have learning difficulties, how difficult it was to concentrate."*

However, despite the challenges, every learning facilitator employed their own practices to enhance the online mentoring process and facilitate mentees so that the negative impact on the mentees, analysed next, could be mitigated.

Impact on Students/mentees

Regarding the interview question about the impact of the change from face-to-face peer mentoring to online mentoring, there was agreement by all interviewees that the impact on students was mainly negative. Giorgos, underlying the difference between face-to-face and online mentoring mentioned:

> *"They're more committed in class […] pay more attention to take notes [...] and they are more prone to study, because they're in the environment of the library (where SASS is located). They see other students in other classes to start doing (mentoring sessions)".*

This could partly explain the significant drop in the number of appointments at SASS depicted in Figure 3. The sharp decline in mentoring sessions taking place in a technology-mediated environment during the COVID -19 era must be attributed to the online environment. As verified by Tina, *"we had a lot less appointments at academic support services, exactly for this reason, because there was absolutely no motivation on the part of the students […] A student is going to seek help from people they trust, not from strangers (meaning learning facilitators)"*

Ioanna commenting on the negative impact of the transition from face-to-face to online peer mentoring raised interesting points about the difference of being taught by a professor from being taught by a peer as well as the difference of the learning environment, be it virtual or real, as a crucial parameter. Specifically, Ioanna stated: "*The mentality of actually having a facilitation session with someone […] not a classroom professor is very different. You take it with a completely different frame of mind. […] I have students who are drinking wine as I was facilitating a session or smoking a cigarette. […] Much more relaxed, informal […] which is because I'm a student, I'm a classmate of theirs. But still […] It's a session. Pay attention. […] sometimes they were really relaxed, like people (learning facilitators) were their friends and somebody to rely on during that difficult period".* This statement challenges the benefit of the online environment being less intimidating for mentees, as mentioned in the literature review, by presenting the downside of such an informal and relaxed atmosphere. Areas for improvement in online peer mentoring are presented next.

Areas for Growth in Online Peer Mentoring

Since contributing to changes in practice necessitates a robust understanding of the practices and how these practices could change, (Saunders, 2012) the last half of the interview questions focused on this. The context of use in this evaluation is

institutional with the emphasis of the practice being quality enhancement and accountability (Saunders, 2012). As a result, responses to the last 3 questions of the interview were centered around the need for change and adaptability providing food for thought as well as certain implications for improvement.

In addition to sharing the challenges they faced, participants talked about the areas they felt could be improved upon to better support themselves when offering peer mentoring online. Based on the responses they shared, all eight participants expressed the need to be provided with more advanced technological products, such as computers, cameras, earphones that will assist them reach out to the mentee more. Giannis stressed the need for reevaluation of teaching techniques and the need to have students more engaged in an online setting. Vasilis continued by describing the idea of attending seminars by experts to enhance their skills while Ioanna highlighted the need for presentation sessions, in particular. To that end, all participants expressed the need to be well trained, so that they can be prepared to mentor students in an online environment and respond to specific student needs in an online setting.

Conclusion

This study addresses a gap in the peer mentoring literature by furthering our understanding of the impact of online peer mentoring on the mentor-mentee relationship. While previous studies of peer mentoring have mainly focused on the experiences of mentees in a classroom environment, this study highlights mentors' experiences in a virtual setting. In line with published research on the significance of establishing social congruence (Rhodes et. al, 2005) this study focused on whether and to what extent an online mentoring environment can foster interactivity and the provision of psychosocial support. The purpose of this study is to gain a deeper understanding of how learning facilitators feel while providing their services online. According to the data derived from the interviews, learning facilitators operate differently in an online space, and this might influence how well they are able to offer peer mentoring and set up meaningful relationships with their mentees. In order for students to receive the benefits of effective peer mentoring services, learning facilitators must deliver these services using the appropriate tools and with positive feelings. The detailed descriptions of the mentors' experiences presented in this paper as opposed to the experiences of mentees, which are commonly presented in literature, although not in a virtual setting as is done in this study, contribute to a holistic perspective and underscore a side that, albeit neglected in literature, offers crucial insight for decision making. Several implications emerge from this analysis. Firstly, both the mentors and the mentees need to set expectations regarding timeliness in communication. In addition, the mentor must ensure availability, confidentiality, and trustworthiness so that the relationship between the mentor and the mentee is built on shared communication as well as mutual respect and equality. Subsequently, mentors need to personalise, contextualise and adapt their mentoring practices to individual mentees, while ongoing training is probably the most crucial contributing factor to a successful online peer education programme (Latino and Unite, 2012). With intentional planning, a technology-mediated mentoring session which enhances both

social and cognitive congruence, can better prepare colleges for a possible prevalence of online peer mentoring in the future.

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An Analytical Study of Diophantine Equations of Pythagorean Form: Causal Inferences on Hypothesized Relations between Quadratic and Non-quadratic Triples

*By Carmelo R. Cartiere**

In XVII century, presumably between 1637 and 1638, with a note in the margin of Diophantus' "Arithmetica", Pierre de Fermat stated that Diophantine equations of the Pythagorean form, $x^n + y^n = z^n$, have no integer solutions for $n > 2$, and $(x, y, z) > 0$. Of this statement, however, Fermat never provided a proof. Only after more than 350 years, in 1994, Prof. Andrew J. Wiles was finally successful in demonstrating it (Wiles, 1995; Taylor & Wiles, 1995; Boston, 2008). However, Wiles' proof adopts calculus techniques far beyond Fermat's knowledge. Our aim is to show an analytical method to attempt a proof to Fermat's last theorem with the only use of elementary calculus techniques.

Keywords: number theory, Diophantine equations, Pythagorean Theorem, Fermat's last theorem, numerical analysis

Preface

"Cubum autem in duos cubos, et quadratoquadratum in duos quadratoquadratos, et nullam in infinitum ultra secundam potestatem in duos ejusdem nominis fas est dividere. Cuius rei demonstrationem mirabilem sane detexi. Hanc marginis exiguitas non caperet."

Translation: Neither a cube into two cubes, nor a biquadrate into two biquadrates, and nothing to the infinite beyond the power of two is possible to divide into two powers with the same name. Of that, I have discovered a truly marvelous proof. But this margin is too small to contain it.

This preface reveals Pierre de Fermat's famous statement, where he explores the extension of the Pythagorean theorem to positive integers. He questions whether there exist triples of numbers (a, b, c) that satisfy the equation $a^n + b^n = c^n$ for values of n greater than 2. The solutions to the Pythagorean equation are known as Pythagorean triples. The assertion that no such triples exist for $n > 2$ became known as Fermat's Last Theorem (Toffalori, 1999). This theorem demanded a proof or disproof that took longer than any of his other conjectures. This study revisits the theorem's proof using elementary calculus techniques, offering new insights into Fermat's historical conjecture.

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Historical Background

Fermat's Last Theorem, first conjectured by the French mathematician Pierre de Fermat in the 17th century, stands as one of the most renowned and enduring problems in mathematics (Cox, 1994). Fermat's claim that the equation $x^n + y^n = z^n$ has no non-trivial integer solutions for $n > 2$ intrigued mathematicians for centuries. Despite numerous attempts by prominent figures such as Euler, Legendre, and Gauss, the theorem remained unproven until the groundbreaking work of Andrew Wiles in the late 20th century (Wiles, 1995; Taylor & Wiles, 1995).

Fermat's marginal notes in his copy of Diophantus's "Arithmetica" sparked a mathematical journey lasting over 350 years. His note claimed to have a "truly marvelous proof" that the margin was too small to contain. This cryptic comment set off an epic quest to solve what was often described as the world's greatest mathematical problem.

Throughout the centuries, numerous mathematicians made significant contributions that indirectly influenced the eventual proof. Leonhard Euler, for instance, proved the theorem for $n = 3$ by innovatively using infinite series and complex numbers. Adrien-Marie Legendre extended the proof to $n = 5$, while Ernst Kummer's work on ideal numbers provided a foundation for understanding the theorem for regular prime exponents.

In the 20th century, new connections were made between Fermat's Last Theorem and other areas of mathematics. Gerhard Frey proposed a link between the theorem and the Taniyama-Shimura-Weil conjecture (now the Modularity Theorem), which suggested that proving the conjecture would also prove Fermat's Last Theorem. This breakthrough set the stage for Andrew Wiles's successful proof.

Wiles's proof, completed in 1994, was a monumental achievement. It utilized sophisticated tools such as Galois representations and properties of elliptic curves, demonstrating the power of combining insights from different areas of mathematics. The resolution of Fermat's Last Theorem not only solved a centuries-old problem but also validated decades of work on elliptic curves and modular forms, influencing contemporary mathematical research.

Fermat's Last Theorem: Early Work and Previous Attempts

The story of Fermat's Last Theorem began with Pierre de Fermat, a French lawyer and amateur mathematician, who is often credited as one of the founders of modern number theory.

During his lifetime, Pierre de Fermat made several significant contributions to number theory, many of which laid the groundwork for his famous theorem. Fermat's work included the development of the method of infinite descent, which he used to prove specific cases of his Last Theorem for small exponents. His work on prime numbers, particularly Fermat's Little Theorem, also played a crucial role in the field.

Fermat proposed the theorem in the margin of his copy of the ancient Greek text "Arithmetica", written by Diophantus. He wrote "I have discovered a truly marvelous proof. But this margin is too small to contain it", setting off a challenge that would

captivate mathematicians for generations. Although Fermat never published a proof of his Last Theorem, his marginal note inspired future mathematicians to pursue the proof rigorously.

Fermat's assertion that $x^n + y^n = z^n$ has no integer non-trivial solutions for $n > 2$ captured the imagination of mathematicians for centuries. Despite numerous attempts by prominent mathematicians over the years, a proof remained elusive for centuries. This inspired an epic quest to solve what has been described as the world's greatest mathematical problem (Singh, 1997; Corry, 2010), until the groundbreaking work of Andrew Wiles in 1994 (Wiles, 1995; Taylor & Wiles, 1995).

The journey towards proving Fermat's Last Theorem is a narrative of collective efforts, filled with partial successes, dead-ends, and incremental progresses in mathematics that advanced the field of number theory and brought mathematicians closer to resolving Fermat's Last Theorem. Each mathematician introduced innovative methods and tackled substantial challenges, contributing to the rich mosaic of mathematical progress leading up to the 20th century. Their work not only addressed Fermat's Last Theorem but also stimulated the development of new areas of mathematics, influencing future generations of mathematicians and their way to approach unsolved problems (Singh, 1997; Corry, 2010).

Leonhard Euler (1707-1783)

Proved Fermat's Last Theorem for $n = 3$.

One of the earliest significant efforts was made by Euler in the 18th century, marking a substantial milestone.

Leonhard Euler, a Swiss mathematician who is often regarded as one of the most prolific mathematicians of all time, successfully proved Fermat's Last Theorem for the case when $n = 3$. His approach involved the innovative use of infinite series and complex numbers, which were groundbreaking at the time.

Euler considered the equation $x^3 + y^3 = z^3$ and reinterpreted it using complex numbers, introducing the concept of imaginary numbers. By factoring the equation in the ring of integers of the form $a + b\omega$, where ω is a primitive cube root of unity (a complex number that, when raised to the power of three, equals one and that is one of the three non-real roots of the equation $x^3 = 1$), Euler examined the properties of these complex numbers to demonstrate that there are no integer solutions to the equation. This method, though pioneering, required justification of the properties of these complex numbers, presenting significant challenges.

Euler's approach laid the groundwork for future developments in number theory, particularly in understanding the properties of numbers within different algebraic structures. His work set a precedent for the analytical rigor required to tackle such problems.

Carl Friedrich Gauss (1777-1855)

Developed foundational principles in number theory and algebra.

Carl Friedrich Gauss, often referred to as "princeps mathematicorum" (the prince of mathematicians), made profound contributions to numerous fields, including number theory. Although Gauss did not directly work on Fermat's Last Theorem, his work on quadratic reciprocity and complex integers provided essential tools that later mathematicians would use. Gauss's concept of Gaussian integers–complex numbers where the real and imaginary parts are integers–expanded the realm of number theory, allowing for more sophisticated methods to be applied to problems like Fermat's Last Theorem.

Gauss's work on number theory, particularly his Disquisitiones Arithmeticae, laid a solid foundation for future researchers. His ideas on congruencies, modular arithmetic, and the properties of prime numbers influenced the work of Ernst Kummer and others who followed.

Adrien-Marie Legendre (1752-1833)

Proved Fermat's Last Theorem for $n = 5$.

Adrien-Marie Legendre, a prominent French mathematician, made significant contributions to the study of Fermat's Last Theorem. Legendre, independently of and almost simultaneously with the German mathematician Carl Friedrich Gauss, provided a proof of Fermat's Last Theorem for the case where $n = 5$. This was one of the first significant cases beyond the initial work Fermat himself did for $n = 4$.

Legendre developed and refined various mathematical techniques that were crucial in the study of Fermat's Last Theorem. His work on number theory, particularly concerning quadratic forms and the distribution of prime numbers, provided foundational tools that were later used in further attempts to prove Fermat's Last Theorem for other values of n.

Legendre's methods and results influenced other mathematicians, such as Ernst Kummer, who later worked on Fermat's Last Theorem using advanced algebraic techniques. Kummer's work on ideal numbers in the ring of integers of cyclotomic fields was inspired by the groundwork laid by mathematicians like Legendre.

Legendre's findings on Fermat's Last Theorem were published and disseminated in mathematical circles, contributing to the broader efforts to solve this challenging problem. His work was well-regarded and helped to keep the interest in Fermat's Last Theorem alive among mathematicians of the 19th century. Although Legendre did not solve Fermat's Last Theorem for all n, his contributions were vital steps in the long journey toward its eventual proof by Andrew Wiles in 1994.

Sophie Germain (1776-1831)

Made progress on Fermat's Last Theorem for Germain Primes.

Sophie Germain introduced other innovative approaches, such as establishing criteria under which the theorem holds true for certain classes of prime exponents. Germain's work, while not providing a complete proof, laid the groundwork for later developments by showing that if certain conditions were met, then no solutions could exist.

Sophie Germain, a French mathematician of the early 19th century, made profound contributions despite the societal challenges she faced as a woman in a male-dominated field. Germain developed novel approaches to Fermat's Last Theorem, especially for the case when n is a prime number. Her strategy was to show that if there are no solutions to $x^n + y^n = z^n$ in integers x, y, z that are not divisible by n, then there are no solutions at all.

Germain's theorem established criteria under which the theorem holds for a large class of prime exponents, demonstrating that for many primes, Fermat's Last Theorem could not have non-trivial solutions. Despite working in isolation and often using a male pseudonym to correspond with other mathematicians, Germain made significant steps. Her methods and results provided critical insights and tools that helped later mathematicians' approaches to the problem.

Ernst Eduard Kummer (1810-1893)

Proved Fermat's Last Theorem for regular primes using ideal numbers.

The 19th century saw further advancements, with mathematicians like Ernst Eduard Kummer introducing the new concept of ideal numbers and employing techniques from algebraic number theory to prove the theorem for a wide range of exponents. Kummer's approach, which involved unique factorization in the ring of integers of cyclotomic fields, was a breakthrough in understanding the structure of solutions to Diophantine equations.

Kummer's work focused on the theorem for regular prime exponents, which eventually led to significant progress in proving the theorem for many specific cases. He introduced the concept of ideal numbers, which extended the notion of integers to a more general setting. This innovation allowed him to tackle problems of unique factorization in certain algebraic structures.

Kummer classified prime numbers into regular and irregular primes and proved that Fermat's Last Theorem holds for all regular prime exponents. Regular primes are those for which certain divisibility conditions involving Bernoulli numbers are satisfied. His work involved detailed examinations of the properties of cyclotomic fields, which are number fields obtained by adjoining a primitive root of unity to the rational numbers. By exploring the arithmetic within these fields, Kummer established results for a wide range of exponents.

However, Kummer's techniques required the development of new mathematical tools and concepts, which were not widely understood or accepted at the time. His work was initially met with skepticism but later became foundational in the field of algebraic number theory.

Early 20th Century: Advancements in Algebra and Number Theory

David Hilbert (1862-1943)

Influenced future approaches.

The early 20th century saw continued efforts to prove Fermat's Last Theorem, with contributions from mathematicians such as David Hilbert, who included the theorem in his famous list of 23 unsolved problems in 1900.

Hilbert's rigorous approach to mathematics and his emphasis on the formalization of mathematical theories influenced the methodologies used by later mathematicians in their attempts to solve Fermat's Last Theorem. His work on algebraic number fields and class field theory provided essential tools and insights that were later used by Andrew Wiles in his proof.

Gerhard Frey (1944-)

Linked Fermat's Last Theorem to elliptic curves.

In the 20th century, new connections were made between Fermat's Last Theorem and other areas of mathematics. Gerhard Frey proposed a link between Fermat's Last Theorem and the Taniyama-Shimura-Weil conjecture (now the Modularity Theorem), suggesting that a proof of the conjecture would imply a proof of Fermat's Last Theorem. This connection was a breakthrough that set the stage for Andrew Wiles' successful proof.

Barry Mazur (1937-)

Developed important techniques in the study of elliptic curves and modular forms.

Barry Mazur's work on the arithmetic of elliptic curves and modular forms was instrumental in the progress toward proving Fermat's Last Theorem. His contributions provided critical insights and techniques that were utilized by Andrew Wiles and others in their work on the Modularity Theorem.

Mazur's research on the structure of rational points on elliptic curves and his development of the theory of deformation rings were particularly important in the context of Wiles' proof. Mazur's influence extended to the broader mathematical community, inspiring further research and advancements in number theory.

The Modern Era: Elliptic Curves and Modular Forms

This period also saw advancements in algebra and number theory that were essential for the eventual proof. Mathematicians developed a deeper understanding of field theory, group theory, and the properties of algebraic structures, all of which contributed to the broader mathematical landscape.

Despite these significant advances, a general proof of Fermat's Last Theorem remained elusive. The problem continued to challenge and inspire mathematicians, leading to a proliferation of partial results and new mathematical techniques. It wasn't until the late 20th century that the combined efforts of many mathematicians culminated in Andrew Wiles' groundbreaking proof, which leveraged the modularity theorem for elliptic curves.

The latter half of the 20th century brought new insights and tools that would prove crucial in the final proof of Fermat's Last Theorem. The development of the theory of elliptic curves and modular forms provided a new framework for approaching the problem. Mathematicians such as Yutaka Taniyama and Goro Shimura proposed conjectures that linked these two areas, suggesting that every elliptic curve is modular – a key idea that Andrew Wiles would later use.

Elliptic Curves

Elliptic curves, despite their name, aren't solely defined by being elliptical shapes but rather by their algebraic properties, which can be described by equations of the form $y^2 = x^3 + ax + b$, having rich structures and properties that made them powerful tools in number theory.

Here, a and b are constants, and the curve is defined over a particular field, often the real numbers or the complex numbers, but frequently over finite fields as well, which is crucial for applications in cryptography.

What makes elliptic curves particularly fascinating is their rich mathematical structure and wide-ranging applications. Here are some key aspects:

Group Structure

One of the most important features of elliptic curves is their group structure. Points on the curve can be added together in a way that forms an abelian group. This group structure is essential in many cryptographic protocols, such as elliptic curve cryptography (ECC), where the difficulty of solving certain mathematical problems associated with elliptic curves forms the basis of secure communication.

Modularity

As mentioned earlier in relation to Wiles' proof, elliptic curves are deeply connected to modular forms through the modularity theorem. This connection is

crucial for understanding the behavior of elliptic curves over certain fields, particularly in the context of number theory.

Rational Points

Understanding the rational solutions (or points with rational coordinates) on elliptic curves is a central problem in number theory. The study of rational points on elliptic curves has connections to the arithmetic of elliptic curves, Diophantine equations, and the Birch and Swinnerton-Dyer conjecture, which remains one of the most important unsolved problems in mathematics.

Visual Beauty

While the mathematical properties of elliptic curves are profound, they also possess a visual elegance. Graphing elliptic curves can reveal intricate symmetries and patterns, making them objects of aesthetic fascination as well as rigorous study.

Applications

Beyond cryptography, elliptic curves find applications in various other areas of mathematics and science. They appear in diverse fields such as coding theory, factorization algorithms, and even in string theory in theoretical physics.

Modular Forms

Modular forms, complex functions with specific transformation properties, provided another perspective on these curves. The Taniyama-Shimura-Weil conjecture, which postulated that every rational elliptic curve is modular, became a central focus in the quest to prove Fermat's Last Theorem.

Modular forms are a type of complex analytic function that exhibit a high degree of symmetry with respect to a particular group of transformations, known as the modular group. These functions play a crucial role in several areas of mathematics, including number theory, algebraic geometry, and mathematical physics. Here are some key aspects of modular forms:

Transformation Properties

Modular forms are characterized by their transformation properties under the action of the modular group, often involving fractional linear transformations by these matrices. The modular group, denoted $SL(2,\mathbb{Z})$, consists of 2×2 matrices with integer entries and determinant 1. However, the modular group is more accurately described by $PSL(2,\mathbb{Z})$, which is the projective special linear group.

Holomorphicity

Modular forms are holomorphic functions, meaning they are complex analytic and have no singularities in the complex plane. This regularity property makes them amenable to techniques from complex analysis, enabling mathematicians to study their properties using tools such as contour integration and power series expansions.

Weight and Level

Modular forms are typically classified according to their weight and level. The weight of a modular form refers to its transformation behavior under the scaling action of the modular group. The level of a modular form corresponds to the congruence subgroup of the modular group that it respects. Different levels and weights give rise to different families of modular forms with distinct properties.

Fourier Expansions

One of the key features of modular forms is their Fourier expansions, which express the function as a sum of exponential functions (Fourier series) with coefficients determined by the properties of the modular form. These expansions provide valuable information about the behavior of modular forms and are often used in computational and theoretical investigations.

Applications

Modular forms have diverse applications across mathematics and physics. In number theory, they play a crucial role in the study of modular forms and elliptic curves, including Wiles' proof of Fermat's Last Theorem. In mathematical physics, modular forms appear in the context of conformal field theory and string theory, providing insights into the structure of space-time and quantum phenomena.

Modularity Theorem

The modularity theorem, conjectured by Pierre Deligne and proved by Andrew Wiles and Richard Taylor, establishes a deep connection between modular forms and elliptic curves. It states that certain types of elliptic curves are associated with modular forms, providing a powerful tool for studying the arithmetic properties of elliptic curves and related objects.

Andrew Wiles and the Final Proof

Andrew Wiles (1953-)

Achieved the final proof.

The culmination of centuries of mathematical progress came with Andrew Wiles, a British mathematician who dedicated much of his career to proving Fermat's Last Theorem. Wiles' approach, built on the foundation laid by his predecessors, involved proving a special case of the Modularity Theorem. In 1994, after seven years of intense work and an initial setback due to a flaw in his proof, Wiles, with the help of his former student Richard Taylor, successfully proved the Modularity Theorem for semistable elliptic curves (Wiles, 1995; Taylor & Wiles, 1995), which in turn proved Fermat's Last Theorem.

Wiles' proof was a monumental achievement, not only for resolving Fermat's Last Theorem but also for the methods and techniques it introduced. His work demonstrated the power of combining insights from different areas of mathematics, such as algebraic geometry, number theory, and modular forms.

The proof of Fermat's Last Theorem had a profound impact on mathematics: it validated decades of work on elliptic curves and modular forms and produced further research in these areas. The techniques developed by Wiles and others continue to influence contemporary mathematical research, including work on the Langlands Program, which seeks to relate number theory and representation theory.

Actual Proof of Fermat's Last Theorem

Wiles' proof of Fermat's Last Theorem is a masterpiece of mathematical synthesis, combining elements of number theory, algebraic geometry, and the theory of modular forms. By proving the Modularity Theorem for semistable elliptic curves and leveraging the properties of Galois representations and Ribet's Theorem, Wiles resolved a problem that had eluded mathematicians for centuries, providing a definitive proof of Fermat's Last Theorem.

Wiles' proof can be roughly divided into several key steps, each building upon the insights gained from the preceding ones. Initially, he focused on establishing a link between elliptic curves and modular forms through what is known as the modularity theorem. This theorem, which was originally conjectured by mathematician Pierre Deligne, asserts that certain types of elliptic curves are associated with modular forms. Wiles made significant strides in proving this conjecture, culminating in what is now known as the modularity theorem, a crucial component of his proof.

Once Wiles established the connection between elliptic curves and modular forms, he turned his attention to proving the specific case of Fermat's Last Theorem. This involved demonstrating that certain elliptic curves, known as modular elliptic curves, satisfy certain properties that are essential for the theorem's validity. Wiles employed a variety of advanced mathematical techniques, including the use of Galois representations and techniques from algebraic geometry, to establish the necessary conditions for these curves to exist.

One of the most remarkable aspects of Wiles' proof is its interdisciplinary nature: drawing on insights from algebraic geometry, number theory, complex analysis, and group theory, Wiles crafted a proof that transcended traditional

boundaries within mathematics. His ability to synthesize ideas from diverse areas of mathematics highlights the power of collaboration and interdisciplinary thinking in tackling complex mathematical problems.

In addition to the technical aspects of his proof, Wiles' work also exemplifies the perseverance and dedication required to tackle longstanding mathematical conjectures. His proof of Fermat's Last Theorem represents the culmination of years of intense research and collaboration with other mathematicians. Wiles' unwavering commitment to solve one of mathematics' most enduring mysteries serves as an inspiration to aspiring mathematicians everywhere.

The actual proof of Fermat's Last Theorem, provided by Andrew Wiles, is deeply rooted in advanced mathematical concepts, specifically (Joshi, 2000):

1. *Modularity Theorem (formerly Taniyama-Shimura-Weil Conjecture)*

   The cornerstone of Wiles' proof is the Modularity Theorem, which he proved for semistable elliptic curves. The theorem postulates that every elliptic curve over the rational numbers can be associated with a modular form. Elliptic curves are smooth, projective algebraic curves of genus one with a specified point called the origin. Modular forms are complex analytic functions invariant under certain transformations and satisfy specific conditions. Demonstrating that all semistable elliptic curves are modular was crucial, establishing a necessary connection between elliptic curves and modular forms.

2. *Connection to Elliptic Curves and Galois Representations*

   Wiles' approach further integrates the properties of elliptic curves and modular forms through the study of Galois representations. Galois representations are homomorphisms from the absolute Galois group of the rational numbers to the automorphism group of a vector space, providing a way to study field extensions. Wiles, along with Richard Taylor, linked Fermat's Last Theorem to these properties by showing that a counterexample to Fermat's Last Theorem would imply the existence of a non-modular elliptic curve. This connection was crucial, exploiting the relationship between elliptic curves and modular forms to address the theorem.

3. *Ribet's Theorem*

   The final piece in Wiles' proof came from Jean-Pierre Serre and Ken Ribet's work, specifically Ribet's Theorem. Ribet's Theorem demonstrated that if an elliptic curve associated with a hypothetical solution to Fermat’s equation were non-modular, it would contradict the Modularity Theorem. This relationship provided the necessary conditions to prove Fermat's Last Theorem. By showing that a solution to Fermat's equation for $n > 2$ would imply the existence of a non-modular elliptic curve, Wiles effectively used Ribet's Theorem to connect the Modularity Theorem to Fermat's Last Theorem.

A Novel Approach to Proving Fermat's Last Theorem by Applying Elementary Calculus Techniques

While various methods have been developed to tackle Diophantine equations – including algebraic, geometric, and computational approaches – analytical methods play a crucial role in establishing theorems and proofs in number theory.

Previous research on Fermat's Last Theorem has primarily focused on algebraic and number-theoretic techniques, such as modular forms, elliptic curves, and algebraic number theory. These advanced methods, while successful in proving the theorem, often require sophisticated mathematical machinery beyond the reach of elementary calculus.

The analytical study presented in this paper aims to bridge the gap between Fermat's Last Theorem and elementary calculus. By adopting a systematic approach grounded in fundamental principles of calculus, this study offers a novel perspective on the problem, providing insights into the nature of Diophantine equations and the possibility of proving Fermat's Last Theorem using elementary techniques.

By employing a proof by contradiction, we start with the base case of a logical equivalence, performing arithmetic manipulations to derive an equivalent homogeneous equation. Introducing another exponent greater than the initial one, we assume a solution exists, and demonstrate, through mathematical transformations and the first law of exponents, that this leads to a contradiction.

This section outlines the structured methodologies we used to deal with the problem, which are rooted in foundational mathematical principles.

The Case of Pythagorean Triples

Fermat's Last Theorem, which postulates that there are no whole number solutions to the equation $x^n + y^n = z^n$ for $n > 2$, has challenged mathematicians for centuries.

To refine our understanding of the theorem's scope, Fermat's statement can be expressed in a generalized form with a double implication:

$$z^n = x^n + y^n \quad \Leftrightarrow \quad z^{n+\alpha} \neq x^{n+\alpha} + y^{n+\alpha}$$
$$(x, y, z, n, \alpha) \in \mathbb{N}$$

This can be interpreted as "the solution of any Diophantine equation in a given Pythagorean form for some exponent $n \in N$, cannot be satisfied in the same Pythagorean form for every other exponent $n + \alpha \in \mathbb{N}$".

To start, we adopt a proof by contradiction, commencing with the base case of the logical equivalence on which we perform simple arithmetic to derive an equivalent homogeneous equation. Therefore, by introducing another exponent $n + \alpha > n$, we assume the contrary to Fermat's statement and suppose a solution. Through a series of mathematical manipulations and applications of the first law of exponents, we arrive at an inequality contradicting our assumption and thus proving Fermat's statement

using a method accessible to mathematicians only familiar with foundational mathematical principles.

We begin with the base case of Fermat's Last Theorem ($n = 2$):

$$x^n + y^n = z^n \quad (1)$$

and divide both sides by z^n to obtain an equivalent homogeneous equation:

$$x^n + y^n = z^n \quad \Leftrightarrow \quad \frac{x^n + y^n}{z^n} = 1$$

that by simple manipulation becomes:

$$\frac{x^n}{z^n} + \frac{y^n}{z^n} = 1 \quad (2)$$

We now introduce another exponent greater than n, denoted as $n + \alpha$, and assume that there exists a solution to the equation for some $n + \alpha$:

$$x^{n+\alpha} + y^{n+\alpha} = z^{n+\alpha} \quad (3)$$

Dividing both sides of the assumed solution by $z^{n+\alpha}$, we introduce another equivalent homogeneous equation:

$$\frac{x^{n+\alpha} + y^{n+\alpha}}{z^{n+\alpha}} = 1$$

from which, by simple manipulation, we obtain:

$$\frac{\mathrm{x}^{\mathrm{n}+\alpha}}{\mathrm{z}^{\mathrm{n}+\alpha}} + \frac{\mathrm{y}^{\mathrm{n}+\alpha}}{\mathrm{z}^{\mathrm{n}+\alpha}} = 1 \quad (4)$$

Let:

$$\mathrm{A} = \left(\frac{x}{z}\right) \quad \text{and} \quad \mathrm{B} = \left(\frac{\mathrm{y}}{\mathrm{z}}\right)$$

We can now write the (2) as:

$$A^n + B^n = 1$$

and the (4) as:

$$A^{n+\alpha} + B^{n+\alpha} = 1 \quad (5)$$

Since A and B are proper fractions, we have $0 < (A, B) < 1$ with the following implications:

$$A^{n+\alpha} = A^n A^\alpha < A^n \quad and \quad B^{n+\alpha} = B^n B^\alpha < B^n$$

for which we can write:

$$A^{n+\alpha} + B^{n+\alpha} < A^n + B^n$$

Hence, with the substitution of the second member, we have:

$$A^{n+\alpha} + B^{n+\alpha} < 1 \quad (6)$$

which contradicts the equivalence in (5) and proves that in the case of Pythagorean triples there cannot exist integer solutions for Diophantine equations in Pythagorean form for $n > 2$.

(Q.E.D.)

The Case of Non-Pythagorean Triples

Non-Pythagorean triples are sets of integers that do not satisfy the Pythagorean theorem. As such, we start from the assumption that no integer solutions exist for $x^2 + y^2 = z^2$ and, according to Fermat's Last Theorem, also no integer solutions exist for any integer for $n > 2$.

Thus, proving Fermat's Last Theorem for non-Pythagorean triples requires establishing an argument where we start from the base case and confirm its implications for higher exponents.

We write the base case as ($n = 2$):

$$X^n + Y^n \neq z^n \quad (7)$$

Dividing both sides of the (7) by z^n we obtain the following equivalent homogeneous inequality:

$$\frac{X^n}{z^n} + \frac{Y^n}{z^n} \neq 1 \quad (8)$$

Let:

$$\mathrm{A} = \left(\frac{X}{z}\right) \quad \text{and} \quad \mathrm{B} = \left(\frac{\mathrm{Y}}{\mathrm{z}}\right)$$

Then, the (8) can be written as:

$$A^n + B^n \neq 1 \quad (9)$$

We have now the following two cases to investigate:

Case 1: $A^n + B^n < 1$.

Since A and B are proper fractions, and therefore less than 1, we know that raising them to any positive integer power will further reduce their value. And therefore, because of our initial condition, we have:

$$A^{n+\alpha} + B^{n+\alpha} < A^n + B^n < 1$$

that maintains the inequality structure of $A + B$ when moving from n to $n + \alpha$, as per the order-preserving property of exponentiation, and validates the (9).

Case 2: $A^n + B^n > 1$.

We can write this condition as $A^n + B^n = 1 + \epsilon \quad (\epsilon > 0)$. Since it is $A^{n+\alpha} < A^n$ and $B^{n+\alpha} < B^n$, we proceed defining the distances δ_α and δ_β,

which will represent the reduction in the exponentiation of A and B as we move from n to $n + \alpha$:

$\delta_\alpha = A^n - A^{n+\alpha}$ and $\delta_\beta = B^n - B^{n+\alpha}$

From this, it follows that:

$A^{n+\alpha} = A^n - \delta_\alpha$ and $B^{n+\alpha} = B^n - \delta_\beta$

Hence, we can establish the following equivalence:

$$A^{n+\alpha} + B^{n+\alpha} = (A^n - \delta_\alpha) + (B^n - \delta_\beta)$$

which, through simple manipulation, transforms into:

$A^{n+\alpha} + B^{n+\alpha} = A^n + B^n - (\delta_\alpha + \delta_\beta)$

and by substituting $A^n + B^n$ with $1 + \epsilon$, we obtain:

$$A^{n+\alpha} + B^{n+\alpha} = 1 + \epsilon - (\delta_\alpha + \delta_\beta) \quad (10)$$

Given ϵ as any arbitrary positive value, we can now determine what possible conditions can follow, thus refining the domain of solutions:

2a: $\delta_\alpha + \delta_\beta < \epsilon$ (the sum of distances is smaller than ϵ).

This condition can be met.

It is $\epsilon - (\delta_\alpha + \delta_\beta) = k$, therefore $1 + \epsilon - (\delta_\alpha + \delta_\beta) = 1 + k > 1$. And (10) becomes:

$$A^{n+\alpha} + B^{n+\alpha} = 1 + k > 1$$

This maintains the integrity of the initial inequality:

$$A^n + B^n > 1$$

validating (9), as per the order-preserving property of exponentiation for the same value of exponents (Euler, 1748; Mitrinovic, Pečarić, & Fink, 1991).

2b: $\delta_\alpha + \delta_\beta > \epsilon$ (the sum of distances is greater than ϵ).

This condition can never be met.

It would imply $\epsilon - (\delta_\alpha + \delta_\beta) = -k$, consequently we have $1 + \epsilon - (\delta_\alpha + \delta_\beta) = 1 - k < 1$. And (10) would become:

$A^{n+\alpha} + B^{n+\alpha} = 1 - k < 1$

This would reverse the order of values from the initial assumption:

$A^n + B^n > 1$

contradicting the principle that inequalities must remain unchanged under exponentiation with the same value of exponents (Euler, 1748; Mitrinovic, Pečarić, & Fink, 1991).

2c: $\delta_\alpha + \delta_\beta = \epsilon$ (the sum of distances is equal to ϵ).

This condition can never be met.

It would imply $\epsilon - (\delta_\alpha + \delta_\beta) = 0$, and therefore $A^{n+\alpha} + B^{n+\alpha} = 1$, which contradicts the order-preserving property of exponentiation, which should maintain the relative inequality structure for the same value of exponents (Euler, 1748; Mitrinovic, Pečarić, & Fink, 1991).

All the above indicates that, in the case of non-Pythagorean triples, integer solutions for Diophantine equations in Pythagorean form do not exist for $n > 2$. (Q.E.D.)

Proof Summary

The proof adheres to elementary techniques and logically demonstrates the impossibility of integer solutions for $n > 2$, for both Pythagorean and non-Pythagorean triples, consistent with Fermat's Last Theorem and offering a novel perspective on the theorem and its proof. The following steps outline the approach taken in this study:

- **Base case:** start with $n = 2$ and establish $x^n + y^n = z^n$.
- **Incremental extension:** introduce α such that $n + \alpha > n$.
- **Homogeneous equations:** normalize both equations for n and $n + \alpha$.
- **Combining and simplifying** equate the ratios and analyze.
- **Contradiction:** show that the ratio $\frac{x^{n+\alpha}+y^{n+\alpha}}{z^{n+\alpha}}$ leads to a contradiction for integer solutions.
- **Generalization:** introduce the order-preserving property of exponentiation to cover all non-Pythagorean triples.

Detailed Analysis of the Proof

Assumption of Base Case and Incremental Condition

1. Base case for $n = 2$
   We start with the base case:
   $$x^n + y^n = z^n$$
2. Introduction of increment α
   We introduce an increment α such that $n + \alpha > n$. This increment allows us to explore the implications of extending the equation to higher powers.

Homogeneous Equations and Manipulation Techniques

3. Homogeneous equation for $n = 2$
   We divide both sides of the equation $x^n + y^n = z^n$ by z^n to obtain an equivalent homogeneous form:
   $$\frac{x^n + y^n}{z^n} = 1$$
   that transforms into:

$$\frac{x^n}{z^n} + \frac{y^n}{z^n} = 1$$

4. Homogeneous equation for $n + \alpha$
   Consider the extended case $x^{n+\alpha} + y^{n+\alpha} = z^{n+\alpha}$ and divide by $z^{n+\alpha}$ to obtain an equivalent homogeneous equation:
   $$\frac{x^{n+\alpha} + y^{n+\alpha}}{z^{n+\alpha}} = 1$$
   that transforms into:
   $$\frac{x^n}{z^n}\frac{x^\alpha}{z^\alpha} + \frac{y^n}{z^n}\frac{y^\alpha}{z^\alpha} = 1$$

Analysis and Derivation of Contradiction

5. Analyzing the ratios
   Because all ratios in which the numerator is smaller than the denominator are proper fractions, as such less than 1, we can state the following inference:
   $$\frac{x^n}{z^n}\frac{x^\alpha}{z^\alpha} < \frac{x^n}{z^n} \quad and \quad \frac{y^n}{z^n}\frac{y^\alpha}{z^\alpha} < \frac{y^n}{z^n}$$

6. Deriving the contradiction and conclusion
   Because $\frac{x^n}{z^n}\frac{x^\alpha}{z^\alpha} < \frac{x^n}{z^n}$ and $\frac{y^n}{z^n}\frac{y^\alpha}{z^\alpha} < \frac{y^n}{z^n}$ then $\frac{x^{n+\alpha}+y^{n+\alpha}}{z^{n+\alpha}}$ cannot be 1. Therefore, we have a contradiction showing that there can be no integer solutions for $n > 2$.

Generalization to all $n > 2$

1. Base case validity
   We have shown that the assumption holds for $n = 2$.
   By extending this to $n + \alpha$ where $\alpha > 0$, we cover all higher powers.

2. Inductive argument
   Proving the base case and showing that the property does hold for $n + \alpha$ effectively covers all cases where $n > 2$. This technique is akin to mathematical induction, ensuring that no integer solutions exist for any $n > 2$.

Generalization to Non-Pythagorean Triples

For non-Pythagorean triples, the method to be adopted involves the order-preserving property of exponentiation, ensuring that the general case for $n > 2$ holds as well.

Conclusion and Validity

Conclusion

This study has presented a novel analytical approach to Diophantine equations of the Pythagorean form, with a specific focus on Fermat's Last Theorem, and provides the necessary reasoning to confirm the possibility of proving Fermat's Last Theorem using elementary calculus alone.

We revisit Fermat's Last Theorem through the lens of elementary calculus, providing a novel perspective on proving the theorem. By adopting a systematic approach grounded in fundamental principles of calculus, we offer insights into the nature of Diophantine equations and the possibility of proving Fermat's Last Theorem using elementary techniques.

Fermat's Last Theorem, which asserts that there are no integer solutions to $x^n + y^n = z^n$ for $n > 2$, posed a significant challenge to mathematicians for centuries. The proof by Andrew Wiles, leveraging advanced concepts like the Modularity Theorem, was a landmark achievement in mathematics. However, our study explores an analytical method to attempt a proof using only elementary calculus techniques.

By employing a proof by contradiction and using arithmetic manipulations and mathematical transformations, we demonstrate that assuming the existence of a solution leads to a contradiction. This method, rooted in foundational mathematical principles, confirms the impossibility of integer solutions for $n > 2$, aligning with Fermat's original assertion.

The significance of Fermat's Last Theorem extends beyond its proof. It serves as a powerful educational tool, illustrating the persistence and creativity required in mathematical research. The theorem's narrative, from Fermat's marginal note to Wiles's proof, inspires mathematicians and students, highlighting the importance of tackling difficult problems and the rewards of innovative thinking.

In conclusion, this study bridges the gap between elementary calculus and advanced number theory, offering a novel approach to understanding and proving Fermat's Last Theorem. Future research may build on this foundation, exploring the applicability of these methods to other unresolved mathematical conjectures.

Historical Significance and Methodological Innovations

Fermat's Last Theorem, stated by Pierre de Fermat in 1637, became one of the most famous and challenging problems in mathematics. The theorem's resolution in 1994 by Andrew Wiles marked a significant milestone, not only for the field of number theory but also for mathematics as a whole. The journey to the proof saw the development of new mathematical concepts, tools, and collaborations that transformed how mathematicians approach problems.

Wiles' work utilized sophisticated tools such as Galois representations and the properties of elliptic curves. These tools have since become essential in various fields of mathematics. Galois representations, for instance, provided a way to understand the symmetries of algebraic equations, bridging the gap between abstract algebra

and number theory. This interplay between different areas of mathematics exemplifies how solving one problem can lead to advancements across multiple domains.

Moreover, the methods developed and refined during the search of a proof have applications in other areas of mathematics and science. For instance, elliptic curves are now a fundamental tool in cryptography, underpinning the security of many modern encryption systems. The deep insights gained from studying these curves and their properties have influenced fields ranging from cryptography to theoretical physics.

Educational Impact

The story of Fermat's Last Theorem and its eventual proof has become a powerful educational tool. It serves as a testament to the persistence and creativity required in mathematical research. The theorem's narrative, from Fermat's marginal note to Wiles' seven-year effort to complete the proof, inspires students and mathematicians alike. It highlights the importance of taking on difficult problems and the rewards of innovative thinking.

Educational programs often use Fermat's Last Theorem to illustrate key concepts in number theory and algebra. The theorem's history itself provides a rich context for teaching mathematical proof techniques, the evolution of mathematical ideas, and the significance of rigorous logical reasoning.

Key Insights and Future Directions

Fermat's Last Theorem poses a challenge to the existence of Diophantine equations of the Pythagorean form $x^n + y^n = z^n$ with integer solutions, for $n > 2$ and positive integers x, y, z.

More precisely, Fermat's original statement can be investigated by following the steps outlined in this paper, replacing $n = 2$ in the generalized form:

$$x^2 + y^2 = z^2 \quad \Leftrightarrow \quad x^{2+\alpha} + y^{2+\alpha} \neq z^{2+\alpha}$$
$$(x, y, z, \alpha) \in \mathbb{N}$$

Our proof attempts to establish a contradiction by introducing an additional exponent and manipulating the resulting equations. The steps provide a logical and structured argument using elementary calculus techniques that Fermat could have known, leveraging a contradiction arising from the properties of exponents and ratios.

By applying elementary calculus techniques, we demonstrate the possibility of proving Fermat's assertion using a systematic method that builds upon foundational mathematical principles, confirming the validity of Fermat's Last Theorem for exponents greater than 2, for both Pythagorean and non-Pythagorean triples.

This study bridges the gap between elementary calculus and advanced number theory, highlighting the interplay between exponentiation and logical reasoning. While it primarily focuses on proving Fermat's Last Theorem, its techniques could potentially be applied to other mathematical problems. Future

research may build on this foundation by exploring the applicability of these methods to other unresolved mathematical conjectures.

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