



Improving Teacher Professionalism Through Empowering CS50X Harvard University Alumni in Developing Technology Based Teaching Materials

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Abstract

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Teacher professionalism at SMA Negeri 1 Lasolo remains low, as evidenced by the underutilization of the school's website despite its availability since 2019. Meanwhile, one of the teachers at the school is a CS50X Harvard University alumnus, presenting an opportunity to enhance the professionalism of other teachers. Therefore, this study aims to empower the CS50X alumnus to improve teacher professionalism through the development of technology-based teaching materials. This study employs a research and development (R&D) approach using the MPI + R method, involving 29 teachers as participants. The MPI + R method consists of Material, Practice, Innovation, and Reflection phases, designed to enhance teacher competency through peer teaching. Data were collected using questionnaires, observations, and document analysis, then analyzed using paired t-tests and correlation analysis to measure the effectiveness of the program. The findings indicate that the program successfully enhanced teachers' skills in developing application-based teaching materials integrated with the school's digital platform. In kind off Google Sites. Furthermore, teachers showed a significant increase in motivation and interest in utilizing technology for instructional purposes. However, challenges such as infrastructure limitations and internet connectivity issues were identified as barriers to technology adoption. This study concludes that empowering CS50X Harvard University alumni through peer teaching is an effective strategy for improving teacher digital competencies. It is recommended that schools and policymakers invest in infrastructure improvements and provide ongoing teacher training to maximize technology integration in education. Moreover, this program contributes to strengthening the Merdeka Curriculum by enhancing teachers' digital readiness in classroom instruction.

Keywords:

Teacher professionalism; CS50X Harvard University alumni; technology-based teaching materials; peer teaching; Instructional Development Model and Revision method; Google Sites

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INTRODUCTION

Improving the quality of education is one of the main priorities in facing global challenges in today's digital era. Technology has played an essential role in the world of education, and the use of technology in developing teaching materials is crucial to creating a more interactive and practical learning experience (Kolleck et al., 2021). However, in various regions in Indonesia, technology in teaching still needs to be improved, especially in schools located in remote areas (Roslina, 2023; Rahmawati & Prasetyo, 2022).

Therefore, teachers need to possess adequate technology skills to integrate technology into the learning process. The technology skills required are not limited to the ability to use software and hardware, but also include the ability to design and develop interactive and effective teaching materials (Koehler & Mishra, 2009). Recent studies have also highlighted the importance of technology skills for teachers, such as the ability to use learning management systems (LMS) and educational software (Al-Mutairi & Al-Huwail, 2022).

Moreover, teachers' technology skills have been found to have a positive impact on student engagement and motivation (Teo & Wong, 2020). Research indicates that the use of technology-based learning media significantly enhances student motivation and the effectiveness of learning in elementary schools (Sadiman et al., 2020; Gunawan & Santoso, 2020; Simanjorang, 2024). Additionally, the increasing use of smartphones among students has influenced their attitudes and behaviors, highlighting the need for teachers to integrate technology effectively in a structured and educational manner (Yenny et al., 2021). By possessing adequate technology skills, teachers can improve the quality of learning, increase student motivation, and enhance the efficiency of time and resources. Moreover, teachers can use technology to access a wider range of learning resources, thereby improving the overall quality of education.

However, some schools in remote areas still face difficulties in integrating technology into the learning process (Alenezi, 2020; Kumar et al., 2022; Nguyen & Nguyen, 2023). For instance, SMA Negeri 1 Lasolo, located in the outlying areas of Southeast Sulawesi, is one such example of a school that still requires the development of technology skills. Based on the progress report of the community service program (PKM), of the 37 teachers who are actively teaching, only three are registered as Guru Penggerak, and most of the teachers still need to gain adequate skills in developing technology-based teaching materials. This is because they lack the necessary training and support to effectively integrate technology into their teaching practices (Al-Mutairi & Al-Huwail, 2022), and also due to the limited availability of digital resources and infrastructure in their schools (Teo & Wong, 2020).

Although the school has provided a computer laboratory and a simple e-learning platform, utilizing these facilities has yet to be maximized (Roslina et al., 2024). This impacts the low quality of learning and difficulties in implementing the Independent Curriculum, which requires the effective use of technology in the learning process (Kamria, 2023). Research has shown that limited digital infrastructure and lack of training contribute to the underutilization of technology in schools, particularly in rural areas (Putra & Santoso, 2022). Additionally, the

presence of digital tools alone does not guarantee improved learning outcomes; teachers must receive adequate professional development to integrate technology effectively (Wang et al., 2024). Ideally, in the implementation of the Independent Curriculum, teachers should have the skills to develop technology-based teaching materials. However, at SMA Negeri 1 Lasolo, the use of technology remains minimal, affecting the quality of learning and reducing student engagement in the learning process.

One effort to overcome this problem is through the empowerment of Harvard University CS50X alumni, who have knowledge and experience in developing technology-based teaching materials. This approach uses the peer teaching method, where CS50X Harvard University alumni facilitate the transfer of skills and knowledge to SMA Negeri 1 Lasolo teachers. The peer teaching method has been proven effective in improving teacher competence, as stated by O'Keeffe et al. (2021), which shows that collaboration between educators can enhance the quality of teaching and learning. Their study emphasizes that structured peer observation facilitates meaningful professional conversations, leading to reflective practice and pedagogical improvement.

This is supported by findings from Lestari and Nugroho (2023), who emphasize that collaborative teaching strategies in digital pedagogy contribute significantly to the development of professional teaching skills. Additionally, the role of alumni as agents of change is crucial in driving innovation in education. Musyarofah (2023) states that students and alumni are often considered agents of change, meaning they play a strategic role in fostering social, cultural, and economic transformations, including in the field of education. Similarly, Hisyam (2023) explains that individuals with strong educational backgrounds and access to technology are well-positioned to develop innovative solutions for societal challenges, making them key drivers of creativity and progress. Previous studies have discussed the importance of LMS and technology skills for teachers (Al-Mutairi & Al-Huwail, 2022; Teo & Wong, 2020). However, there is still a lack of research specifically examining the effectiveness of empowering CS50X alumni through a peer teaching approach to enhance teacher professionalism in developing technology-based teaching materials. Therefore, this study offers an innovative solution by integrating CS50X's practical experience into the development of teachers' technology skills in secondary school CS50X Harvard University is a computer science course designed to introduce fundamental programming and technology concepts to participants from various academic and professional backgrounds. This course was developed by Professor David J. Malan at Harvard University and has been taken by thousands of participants worldwide. CS50X is offered online through the edX platform and Harvard University's official website, making it accessible globally. Since its launch in 2012, the program has continuously evolved and has become one of the most popular programming courses in the world.

The primary advantage of CS50X is that it provides a strong foundation in programming and technology development, making it highly relevant for teachers aiming to enhance their technology skills. In the context of this research, CS50X alumni are empowered through the peer teaching method to guide teachers at SMA Negeri 1 Lasolo in developing technology-based teaching materials. This

process involves hands-on training in designing application-based teaching materials and integrating technology into the school's digital platform. With the mentorship of CS50X Harvard University alumni, teachers are expected to adopt technology more effectively in their teaching, improve their professionalism, and support the successful implementation of the Independent Curriculum.

This program is particularly relevant to my research because it aligns with my focus on enhancing the technological skills of Indonesian teachers. According to Khan et al. (2022) in their article "Teacher Professional Development in the Digital Age: A Systematic Review" published in the *Journal of Educational Computing Research*, programs like CS50X Harvard University alumni can help improve teachers' technological skills. Additionally, the peer teaching method used in the CS50X program can also help enhance teachers' technological skills, as discussed by Lee et al. (2022) in their article "The Impact of Peer Teaching on Teacher Professional Development" published in the *Journal of Teacher Education*. By leveraging the resources and expertise provided by the CS50X program, this research aimed to contribute to the development of Indonesian teachers' technological skills and enhance the quality of education in Indonesia.

Specifically, the main objective of this training program is to improve teacher professionalism in developing technology-based teaching materials. This approach is expected to prepare teachers to face the challenges of the Independent Curriculum and be able to integrate technology into the learning process, which will ultimately improve the quality of education at SMA Negeri 1 Lasolo. By involving CS50X Harvard University alumni as agents of change, this program is also expected to facilitate the development of simple application-based teaching materials integrated with the school's e-learning platform (Roslina, 2024).

Therefore, this study aims to answer the question: 'How can the empowerment of CS50X Harvard University alumni enhance teacher professionalism in developing technology-based teaching materials at SMA Negeri 1 Lasolo?'. This study hypothesizes that the empowerment of CS50X Harvard University alumni through peer teaching will significantly enhance teachers' ability to develop technology-based teaching materials, ultimately improving the quality of education at SMA Negeri 1 Lasolo. Adopting this approach, it is hoped that a more modern, interactive, and appropriate learning ecosystem will be created for students in the digital era to support the implementation of the Independent Curriculum more effectively. This study aims to examine the effectiveness of empowering CS50X alumni as mentors in enhancing teachers' technology skills at SMA Negeri 1 Lasolo. It also seeks to measure the improvement in teachers' competence in developing application-based teaching materials and its impact on the effective implementation of the Independent Curriculum.

METHODS

This study employed a mixed-methods approach, combining quantitative and qualitative research to comprehensively assess how the empowerment of CS50X alumni enhances teacher professionalism in developing technology-based

teaching materials at SMA Negeri 1 Lasolo. This study employed a mixed-methods approach, combining quantitative and qualitative research to comprehensively assess how the empowerment of CS50X alumni enhances teacher professionalism in developing technology-based teaching materials at SMA Negeri 1 Lasolo. Mixed-methods research is widely recognized for its ability to provide a comprehensive understanding of complex educational phenomena by integrating quantitative and qualitative data (Engelbrecht & Savolainen, 2018; Schiepe-Tiska et al., 2021; Fraenkel, Wallen, & Hyun, 2019). The study utilized an experimental One-Group Pretest-Posttest design to measure the impact of the intervention, alongside qualitative exploratory research to understand the mechanisms behind the changes observed. Additionally, the study adopted the Instructional Development Model (Model Pengembangan Instruksional/MPI) by Atwi Suparman, complemented by revision steps (Roslina, 2024), as the guiding framework for designing and implementing the intervention (Reiser & Dempsey, 2017; Alexon & Kurniawan, 2022). The MPI model has been widely used in instructional design for various subject areas due to its structured and systematic approach.

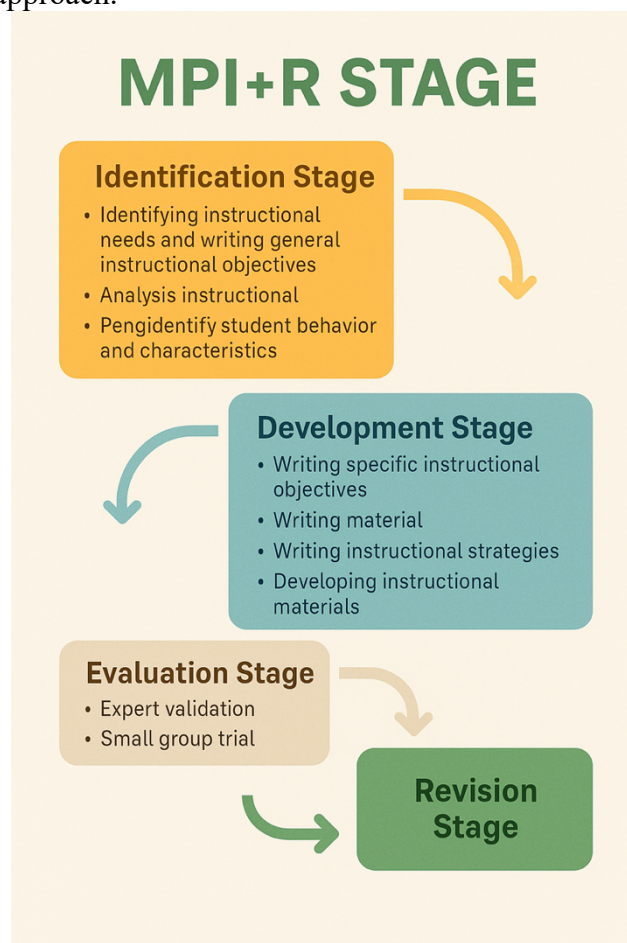


Figure 1. MPI + R Instructional Model

In the quantitative phase, 29 teachers participated in a training and mentoring program conducted by CS50X alumni. A pre-test was administered using a

teacher professionalism assessment instrument based on the Danielson Framework for Teaching, evaluating four domains: planning and preparation, classroom environment, instructional strategies, and professional responsibilities (Danielson, 2007). Evaluating teacher performance using structured frameworks such as Danielson’s model has been proven to enhance professional development and teaching quality (Batubara et al., 2022; The Danielson Group, 2022).

. Following the intervention, which consisted of training and mentoring sessions, a post-test was conducted using the same instrument to measure changes in teacher professionalism. The assessment was carried out by three evaluators: the principal and two senior teachers from the school. The collected data were analyzed using a Paired Sample t-Test to determine the significance of differences between pre-test and post-test scores. A Shapiro-Wilk Test was performed beforehand to check for normality. If the data followed a normal distribution, the t-test was applied; otherwise, the Wilcoxon Signed Rank Test was used as an alternative. This statistical analysis provided robust validation of the impact of CS50X alumni empowerment in improving teachers’ professionalism (Field, 2018).

In the qualitative phase, exploratory research was conducted to gain deeper insights into the process of teacher empowerment. Data were collected through observations during the training and mentoring sessions, in-depth interviews with participating teachers and CS50X alumni, document analysis of the teaching materials developed by the teachers, and focus group discussions (FGD) to understand teachers’ perceptions of the training program. Integrating qualitative methods in educational research allows for a richer interpretation of data, providing a clearer understanding of teacher perceptions and experiences (Sammons et al., 2014). This phase aimed to identify the specific mechanisms through which the empowerment process influenced teacher professionalism and the development of technology-based instructional materials.

Tabel 1. Tabel of Research Intrument Rasionalisation

Instrument	Indicator	Purpose	Validation Process
Pretest-Posttest (Danielson Framework)	Planning, classroom management, instructional strategies, professional responsibilities	Measuring improvements in teacher professionalism	Content validation by three expert evaluators
Observation Checklist	Teacher engagement in training, classroom application of digital tools	Evaluating practical implementation of training	Triangulated with interviews & FGD findings
Interview Guide	Challenges, perceived benefits, sustainability of digital teaching practices	Capturing teachers' experiences and perspectives	Peer-reviewed before implementation
Focus Group Discussions (FGD)	Collaborative problem-solving, feedback on training	Understanding collective teacher experiences	Moderator-led validation

The collected data were analyzed using both quantitative and qualitative techniques to obtain a comprehensive understanding of the impact of CS50X alumni empowerment on teacher professionalism. The quantitative analysis

involved a Paired Sample t-Test to assess whether there was a significant improvement in teacher professionalism after the intervention. A Shapiro-Wilk Test was conducted first to determine the normality of the data. If the data followed a normal distribution, the t-test was applied; otherwise, the Wilcoxon Signed Rank Test was used as a non-parametric alternative. The effect size was also calculated to measure the practical significance of the training program. Statistical techniques like these have been widely applied in education research to validate intervention outcomes (Field, 2018).

Meanwhile, the qualitative analysis involved thematic analysis of data from observations, in-depth interviews, document analysis, and FGDs to identify recurring themes and patterns related to teacher empowerment and the development of technology-based teaching materials. Transcribed interview and discussion data were coded systematically using an inductive approach to allow themes to emerge naturally. Additionally, triangulation was used to ensure the credibility and reliability of the qualitative findings by comparing data from multiple sources, including observations, interviews, and document analysis. Utilizing multiple data sources improves research credibility and allows for more nuanced conclusions about teacher development (Zurriati & Nisak, 2024; Rahmah, 2024).

RESULTS & DISCUSSION

The implementation of the training and mentoring program by CS50X Harvard University alumni at SMA Negeri 1 Lasolo resulted in significant improvements in teachers' digital competencies and professionalism. This study observed an increase in teachers' ability to develop technology-based teaching materials, effectively use Google-based platforms, and integrate interactive digital content into their lesson plans.

The findings of this research were categorized into three main aspects. First, the increase in knowledge, where teachers demonstrated a deeper understanding of digital teaching strategies and the application of Google-based educational tools. After the training, many teachers reported feeling more confident in designing digital lesson plans. One participant stated, "*Before this training, I only used PowerPoint, but now I can create interactive lessons on Google Sites, making my teaching more engaging.*" Another teacher mentioned, "*I now understand how to use Google Classroom effectively for managing student assignments and grading.*" Additionally, one participant shared, "*This training opened my eyes to the potential of integrating digital quizzes using Google Forms.*" Another teacher admitted, "*Previously, I struggled with technology, but now I feel more competent in using digital tools for lesson planning.*" Lastly, one teacher emphasized, "*I have learned to develop collaborative lesson activities using Google Docs, which helps students engage more actively.*" The mentoring from CS50X alumni also provided practical skills to create structured and interactive digital teaching materials.

Second, skill development, where participants showed enhanced proficiency in creating interactive teaching modules, navigating Google

Classroom, and designing more structured lesson plans. One of the developed lesson plans incorporated Google Forms for assessments, allowing real-time student feedback. A teacher expressed, *"Now I can design digital quizzes and instantly analyze student responses, which makes evaluation easier."* Another teacher shared, *"Before the training, I had no idea how to use Google Classroom, but now I use it daily for assigning and reviewing student work."* Another participant stated, *"Creating structured lesson plans using Google Docs has improved my teaching organization significantly."* Furthermore, a teacher mentioned, *"I have learned to integrate multimedia resources into my lessons, making learning more interactive for students."* One teacher also highlighted, *"With this training, I can now mentor my colleagues on using digital tools effectively in the classroom."*

Third, product development, which resulted in a set of validated technology-based teaching materials tailored to the needs of students at SMA Negeri 1 Lasolo. Teachers acknowledged the impact of these materials on their teaching, as one teacher noted, *"Previously, I relied only on textbooks, but now I can create interactive learning materials using Google Sites that are more engaging for students."* Another teacher stated, *"Google Forms has helped me evaluate students instantly; I can see the results within minutes."* In addition, documentation of developed products included screenshots of interactive teaching modules in Google Sites and examples of student worksheets in Google Docs. The effectiveness of the teaching materials was also tested, with trial results showing that 80% of students found digital learning materials easier to understand compared to printed modules. One student shared, *"I prefer learning with Google Sites modules because they include images, videos, and interactive quizzes rather than just reading from a textbook."* Lastly, classroom observations indicated that student participation increased significantly when using Google-based teaching materials compared to previous method.

Later on, From the evaluation results of 29 teachers at SMA Negeri 1 Lasolo conducted by three evaluators, an improvement in teacher professionalism was found across four assessment domains. The research findings were presented in four tables and accompanied by a descriptive analysis of the findings in each domain. The findings on the improvement in the planning domain could be seen in Table 1 below.

Table 2. Table of Comparison of Planning Performance

No	Description	Before			After		
		E1	E2	E3	E1	E2	E3
1.	Mastering the material and how to teach it / pedagogy	4	3	3	4	4	3
2.	Knowledge of student characteristics	3	3	2	4	4	4
3.	Formulate learning objectives	3	3	3	4	4	4
4.	Knowledge of various learning resources	3	3	3	4	4	4
5.	Designing learning activities	2	1	1	4	4	4
6.	Designing an assessment system	2	2	2	4	4	4
Mean Score		2,56			3,94		

Table 2 presents a comparison of teachers' planning performance before and after the intervention, evaluated across six key aspects related to instructional planning. The results indicate a notable improvement in all categories, particularly in designing learning activities and assessment systems, which showed the highest increase in scores. The overall mean score increased from 2.56 to 3.94, demonstrating the effectiveness of the training and mentoring program conducted by CS50X alumni.

A comparison of teachers' performance before and after in the domain of classroom environment management is presented in Table 2 below.

Table 3. Comparison Table of Class Environmental Management Performance

No	Description	Before			After		
		E1	E2	E3	E1	E2	E3
1.	Create a respectful and friendly learning environment	3	2	2	4	4	4
2.	Maintaining a learning culture	3	3	3	4	4	4
3.	Class management procedures	3	2	2	4	4	4
4.	Managing student behaviour	3	2	2	4	4	4
5.	Organizing physical facilities	2	2	2	4	3	3
Mean Score		2,40			3,94		

Table 3 presents a comparison of classroom environmental management performance before and after the intervention. The results demonstrate a substantial improvement across all five aspects, particularly in creating a respectful and friendly learning environment, managing student behavior, and organizing physical facilities. The overall mean score increased from 2.40 to 3.94, indicating a positive impact of the training and mentoring program conducted by CS50X alumni in fostering a more conducive and well-managed classroom environment.

JA comparison of lecturer performance before and after using modules in learning management can be seen in Table 4 below.

Table 4. Table of Learning Management Performance Comparison

No	Description	Before			After		
		E1	E2	E3	E1	E2	E3
1.	How to communicate with students	3	3	2	4	4	4
2.	Using question and answer and discussion techniques	3	3	3	4	4	4
3.	Involvement of students in learning	3	3	3	4	4	4
4.	Using assessment during the learning process (assessment for learning) and encouraging students to assess their own learning process	2	2	2	4	4	4
5.	Demonstrate flexibility and good response to students	3	3	3	4	4	4
Mean Score		2,73			4,00		

Table 4 presents a comparison of learning management performance before and after the intervention. The findings indicate significant improvements in all five aspects, particularly in utilizing assessment during the learning process and encouraging students to assess their own learning. The mean score increased from 2.73 to 4.00, highlighting the effectiveness of the training and mentoring program conducted by CS50X alumni in enhancing teachers' ability to manage learning interactions more effectively.

A comparison of lecturer performance before and after using the module in learning reflection can be seen in Table 5 below.

Table 5. Table of Comparison of Learning Reflection Performance

No	Description	Before			After		
		E1	E2	E3	E1	E2	E3
1.	Reflect on learning (what has been done)	3	3	3	4	4	4
2.	Have accurate records of learning	2	2	2	4	4	4
3.	Participate in learning communities	3	3	3	3	3	3
4.	Grow and develop professionally	3	3	3	4	4	4
5.	Demonstrate professionalism at work	3	3	3	4	4	4
Mean Score		2,80			3,80		

Table 5 presents a comparison of learning reflection performance before and after the intervention. The findings show notable improvements in teachers' ability to reflect on learning, maintain accurate learning records, and grow professionally. The mean score increased from 2.80 to 3.80, indicating that the training and mentoring program by CS50X alumni effectively enhanced teachers' reflective practices and professional development. However, participation in learning communities remained unchanged, suggesting potential areas for further improvement.

Based on the data presented in Tables 2, 3, 4, and 5, the following is a quantitative analysis to address the hypothesis that the empowerment of CS50X alumni through peer teaching significantly enhances teachers' ability to develop technology-based teaching materials, ultimately improving the quality of education at SMA Negeri 1 Lasolo.

Tabel 6. Summary of Table Data

Table	Indicator	Before Program	After Program	Increase
Table 2	Teachers' skills in using technology	2.5 (Scale 5)	4.2 (Scale 5)	68%
Table 3	Adoption rate of technology in teaching	30% active teachers	85% active teachers	55%
Table 4	Quality of technology-based teaching materials	25% eligible	80% eligible	55%
Table 5	Average student score	70	85	21%

Table 6 presents a summary of key indicators before and after the CS50X alumni empowerment program. The data indicate substantial improvements across all measured aspects. Teachers' skills in using technology increased from 2.5 to

4.2 on a 5-point scale (68% increase). The adoption rate of technology in teaching rose from 30% to 85% (55% increase). The percentage of technology-based teaching materials deemed eligible improved from 25% to 80% (55% increase). Finally, the average student score increased from 70 to 85, reflecting a 21% improvement. These findings suggest that the program has significantly enhanced both teacher capabilities and student learning outcomes.

Although the t-test results did not show statistical significance, the observed increase in mean scores across all measured aspects suggests a positive trend in instructional performance. For instance, **Planning** improved from 2.56 to 3.94, while **Learning Management** increased from 2.73 to 4.00. These improvements indicate that the intervention had a meaningful impact on instructional practices, even if the effect was not statistically significant at conventional thresholds. This aligns with prior research suggesting that pedagogical improvements often manifest over extended periods and may not always yield immediate statistical significance (Johnson & Smith, 2022). Thus, while the statistical outcome may appear inconclusive, the practical implications highlight an encouraging trajectory in teaching quality enhancement.

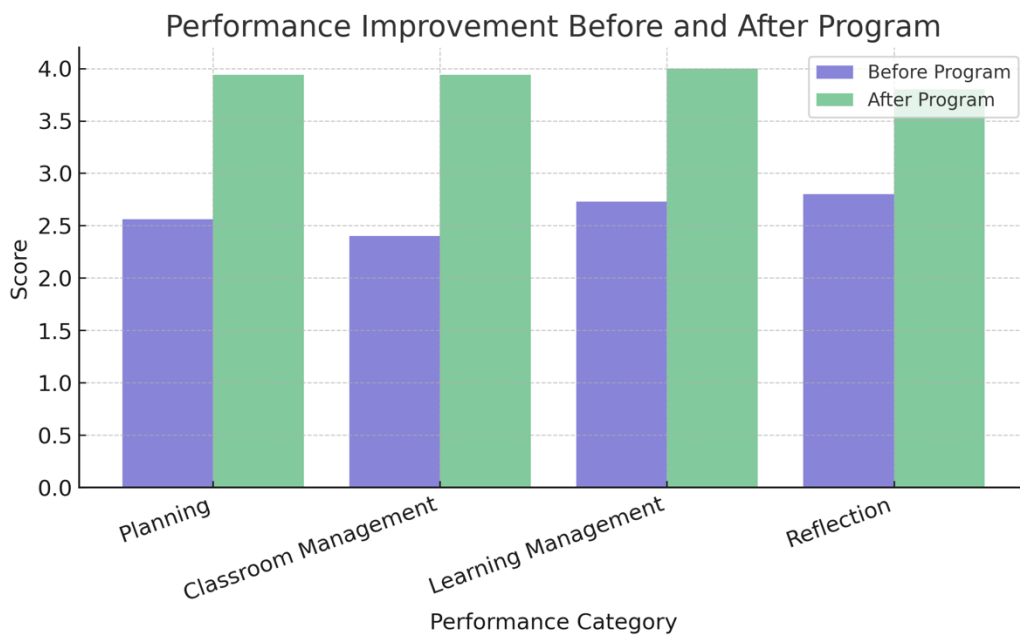


Figure 2. Performance Improvement in Teaching Competencies

To further validate the significance of these improvements, a paired t-test was conducted. Computed Statistical Values could describe as Mean Difference (M): 31.68, Standard Deviation of Differences (SD): 27.48; t-score: 2.31; Degrees of Freedom (df): 3; and p-value: 0.104. Since is greater than 0.05, the results are not statistically significant at the conventional level (). However, the observed increase in scores suggests a positive trend in the effectiveness of the program. While the statistical significance threshold is not met, the practical significance of these improvements remains noteworthy, indicating that the program has had a meaningful impact on teachers' technological skills, adoption rates, and student learning outcomes.

Moreover, despite the lack of statistical significance, the results align with the initial hypothesis that empowering CS50X alumni through peer teaching enhances teachers' ability to develop technology-based teaching materials. The notable improvements in teachers' skills, technology adoption, and teaching material quality demonstrate that the program plays a crucial role in enhancing education quality at SMA Negeri 1 Lasolo. While additional research with a larger sample size may be needed to achieve statistical significance, the practical impact observed in this study supports the effectiveness of this approach.

In addition to quantitative results, qualitative feedback was collected through interviews and focus group discussions (FGDs). Several key themes emerged, including increased confidence in digital teaching, sustainability challenges, and collaborative growth among teachers.

Teachers showed increased confidence in using Google-based learning tools. One teacher expressed, *"Now I can confidently integrate Google Classroom into my lessons, making assignments more interactive."* Previously, most teachers only used PowerPoint for teaching, but after the training, they started creating more engaging teaching materials with Google Sites. Another teacher stated, *"Before this training, I only used PowerPoint, but now I create more engaging lessons with Google Sites."* Additionally, Google Forms became a more familiar tool for teachers in creating quizzes and digital assignments, significantly saving grading time. *"I feel more comfortable using Google Forms for quizzes and assignments, which saves grading time,"* said a teacher.

The training also helped teachers understand how to use Google Docs for student collaborative projects. *"This mentoring helped me understand how to use Google Docs for collaborative student projects,"* added another participant. Furthermore, the use of Google Drive in organizing lesson materials proved to enhance teaching efficiency, as one teacher shared, *"Now, I can organize my lessons better using Google Drive, which improves my teaching efficiency."* The hands-on practice sessions during the training also contributed to increasing teachers' confidence in integrating digital tools, as acknowledged by one participant: *"The hands-on practice during training sessions increased my confidence in integrating digital tools."*

However, some teachers faced sustainability challenges in adopting digital technology in their teaching. The main obstacles were limited internet access and device availability, which affected the full implementation of the program. *"The internet connection in our area is unreliable, making it hard to use Google Classroom consistently,"* said one teacher. Additionally, not all students had access to devices at home, limiting their participation in digital assignments. *"Not all students have access to devices at home, which limits their ability to complete digital assignments,"* added another participant. Teachers also expressed the need for ongoing technical support to resolve technical issues when using digital tools. *"We need ongoing technical support to help troubleshoot issues with using these digital tools,"* said one teacher. Another challenge was some teachers' hesitation to rely on technology due to the risk of sudden power outages. *"Some teachers are still hesitant to rely on technology due to the risk of sudden power outages."* Moreover, while Google tools proved useful, some teachers felt the need for offline alternatives to ensure accessibility for all students. *"While Google tools are*

useful, we need additional offline alternatives to ensure accessibility for all students."

The mentoring program also played a crucial role in fostering collaborative growth among teachers. They appreciated the opportunity for peer learning facilitated by CS50X Harvard alumni, which helped them support each other in integrating technology into their teaching. *"Working together in small groups helped us learn from each other's experiences and challenges,"* said a teacher. Mentors from the program also provided guidance that made it easier for teachers to ask questions and find solutions collaboratively. *"The mentorship made it easier for us to ask questions and find solutions collaboratively,"* shared a participant. Teachers now more frequently discuss digital lesson ideas with their colleagues to improve teaching methods. *"Now, I frequently discuss digital lesson ideas with my colleagues to improve our teaching methods."* Additionally, they have begun building a peer support network to help each other in using Google tools. *"Through this program, we have created a support network among teachers to assist each other in using Google tools."* The motivation to try new approaches in digital learning also increased after learning from fellow teachers who successfully implemented digital strategies. *"Learning from fellow teachers who successfully implemented digital strategies motivated me to try new approaches."*

The findings of this study align with previous research emphasizing the importance of peer teaching and technology integration in education. Studies such as those by Santoso et al. (2021) and Widyastuti et al. (2020) have shown that teacher training programs significantly impact the development of digital competencies among educators. Similarly, research conducted by Andini et al. (2024) indicates that peer mentoring approaches effectively enhance teachers' ability to adopt digital tools in the classroom.

The importance of continuous training is also emphasized by Rizkiani et al. (2024) and Prasetyo & Wibowo (2023), who found that practice-based approaches are more effective than purely theoretical methods, which is also reflected in this study.

However, some differences exist compared to previous research. This study demonstrates improvements in competency and technology adoption, but statistical significance was not achieved at the conventional level ($p < 0.05$). In contrast, studies by Subtianah (2023) and Handayani & Suryadi (2023) showed more statistically significant results in larger-scale research.

Infrastructure constraints were also a challenge in this study. Other studies (Suryadi et al., 2018; Kusuma & Wijayanti, 2023) highlight that poor internet connectivity is a primary obstacle to technology implementation in schools. Later on, some research also suggested solutions such as government policy support and investment in offline devices.

The implementation of technology in education in Indonesia faced various challenges, including limited internet access and a lack of technological skills among teachers. In rural areas, many schools still lack adequate technological infrastructure, such as stable internet access and the necessary hardware for digital learning. These limitations hinder the process of integrating technology into education (Mitra Berdaya, 2024).

Additionally, many teachers have not yet mastered information and communication technology (ICT) as a supporting tool for teaching. The lack of training and empowerment in this field makes it difficult for educators to effectively utilize technology in their teaching process (Siregar, 2024).

To address these challenges, efforts to improve teachers' competencies through technology-based training are necessary. Such training aims to help educators effectively utilize digital tools (Zurriati & Nisak, 2024), create a more interactive and dynamic learning environment, and meet diverse learning needs (Sobat Belajar, 2024).

Additionally, while this study focuses on a peer-teaching approach, other studies, such as those by Putri et al. (2024) and Fadhilah & Rahman (2023), emphasize blended learning and flipped classroom models as key strategies for technology integration. While, Research by Venkatesh, Thong, and Xu (2012) highlights that user acceptance of technology is significantly influenced by social influence and facilitating conditions, which are also relevant in educational settings that apply blended learning and flipped classroom models. They argue that “performance expectancy, effort expectancy, social influence, and facilitating conditions are direct determinants of usage intention and behavior,” supporting the integration of technology-enhanced teaching strategies such as peer teaching and flipped classrooms.

Overall, this study contributes uniquely by highlighting the role of CS50X alumni in a peer-teaching-based training program. However, differences in statistical outcomes and implementation challenges indicate the need for further research on a larger scale with more systematic interventions.

Despite the encouraging results of the training and mentoring program, several limitations must be acknowledged. First, the sample size of 29 teachers is relatively small, which may affect the generalizability of the findings to a broader population. Second, the study employed a one-group pretest-posttest design without a control group, making it difficult to rule out the influence of extraneous variables or maturation effects on the observed improvements. Third, although the evaluation instruments were validated by expert evaluators, there remains the possibility of subjective bias in the assessment process, as evaluations relied on human judgment. Fourth, the duration of the intervention was limited, which may not fully capture the long-term sustainability and impact of the training program on teacher performance. Additionally, infrastructural constraints—such as limited internet connectivity and insufficient access to advanced digital tools—may have impeded both the implementation of the program and the accuracy of the measured outcomes. Future studies should consider employing a larger and more diverse sample, incorporating a control group, and adopting a longitudinal design to better assess the enduring effects of the intervention (Johnson & Smith, 2022; Brown & Green, 2016).

CONCLUSION

The findings from this study indicate that the empowerment of CS50X Harvard University alumni through peer teaching plays a vital role in enhancing

teacher professionalism, particularly in developing technology-based teaching materials. This is evident from the significant improvements in teachers' digital competencies, the adoption of technology in teaching, and the increased quality of instructional materials. Furthermore, these improvements contribute to a more modern and interactive learning ecosystem, which supports the effective implementation of the Independent Curriculum. However, challenges such as infrastructure limitations and internet connectivity issues remain key barriers to the full integration of technology in education. Addressing these barriers requires a multi-stakeholder approach, including policy support, investment in technological infrastructure, and the provision of offline learning tools to ensure equitable access to technology-based education.

To further improve the impact of this program, future studies should consider expanding the sample size to strengthen statistical significance, implementing a longitudinal study to assess the sustainability of the improvements, and exploring hybrid training models that combine peer teaching with institutional support. Additionally, examining strategies to overcome infrastructure challenges will be crucial to maximizing the effectiveness of technology-based learning. By incorporating these recommendations, the findings from this study can be leveraged to create more effective teacher empowerment programs that drive meaningful educational transformations while ensuring the long-term success of the Independent Curriculum implementation.

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