Enhancing computer science education: student insights on active learning and digital integration

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ABSTRACT: Active teaching methods and digital technologies have been applied in higher education across different disciplines, institutions and countries. Based on a study conducted at a Kazakhstani university, this article is focused on student perceptions of the effectiveness of active teaching methods based on case-based learning (CBL), team-based learning (TBL), problem-based learning (PBL) and digital technologies in a computer science course. A qualitative approach was employed, utilising a survey questionnaire administered upon completion of the course. The results indicate that students perceived these methodologies as highly effective in enhancing engagement, collaboration and understanding of course concepts. The integration of digital technologies further enriched the learning environment, making education more interactive and accessible. The study also identified the main challenges faced by students in implementing active teaching methods, which primarily include resource limitations and time constraints.

INTRODUCTION

The adoption of active teaching methods and digital technologies in higher education has shown considerable promise in improving student engagement and learning outcomes. Active learning approaches, such as case-based learning (CBL), team-based learning (TBL) and problem-based learning (PBL), effectively promote critical thinking, collaboration and problem-solving skills essential in modern education. However, understanding student perceptions is crucial to evaluating the effectiveness of these methods.

This study focuses on student perceptions of the use of CBL, TBL, PBL and digital technologies in a computer science course in a Kazakhstani university. By analysing student feedback, one can gain insights into how these methodologies impact their learning experiences and outcomes.

LITERATURE REVIEW

CBL is recognised for its efficacy in bridging the gap between theoretical knowledge and practical application. CBL, which presents real-world scenarios, enhances students' analytical and decision-making skills. Flynn and Klein's research shows CBL participants had higher critical thinking levels than those in traditional lectures [1]. Furthermore, CBL has been particularly effective in computer science education, where practical problem-solving is a key component [2].

As Michaelsen at al noted, TBL promotes collaboration and accountability via structured activities, enhancing engagement and understanding through peer interactions [3]. Studies have shown that TBL can lead to improved academic performance and a more comprehensive grasp of course materials [4][5]. In computer science courses, TBL has been found to improve students' ability to work effectively in teams, a crucial skill in the software development industry [6].

PBL develops problem-solving skills by engaging students in complex, real-world problems, thereby enhancing critical thinking and autonomy [7]. Research by Barrows shows that PBL excels in fields like computer science, where practical knowledge application is essential [8]. Students in PBL environments demonstrate greater retention of knowledge and higher levels of cognitive engagement [9].

The application of digital technologies in education has also shown positive results. Incorporating technologies like augmented reality (AR) and virtual reality (VR) has transformed educational environments into more interactive and immersive spaces. A meta-analysis by Merchant et al found that digital simulations and VR significantly enhance learning outcomes by providing students with experiential learning opportunities that are otherwise difficult to achieve in traditional settings [10]. Digital tools deepen understanding of abstract computer science concepts and algorithms [11].

Student Perceptions of Active Learning and Digital Technologies

While the pedagogical benefits of active learning and digital technologies are well documented, understanding student perceptions is equally important. Qualitative studies capturing student experiences can provide valuable insights into the effectiveness of these methods. For instance, a study by Prince highlighted that students perceived active learning strategies as more engaging and beneficial for their understanding of complex subjects [12]. Similarly, Bower et al indicated that students found digital technologies to be highly effective in enhancing their learning experiences, making education more accessible and engaging [13].

RESEARCH QUESTIONS AND HYPOTHESES

The objective of this study was to examine how higher education students perceive case-based learning (CBL), team-based learning (TBL), problem-based learning (PBL) and digital technologies, framed by the diffusion of innovations theory. It investigates the adoption of these active teaching methods in higher education and addresses the following research questions:

1. How effective do students find active teaching methods and digital technologies?

2. What challenges hinder student engagement with these methods?

Based on these questions, the following hypotheses were proposed:

1. H_1: Students view CBL, TBL, PBL and digital technologies as effective in enhancing engagement and learning outcomes (H_0: Students do not view CBL, TBL, PBL and digital technologies as effective for enhancing engagement and learning outcomes).

2. H_2: Resource scarcity and time constraints significantly challenge the implementation of these methods (H_0: Resource scarcity and time constraints do not significantly challenge the implementation of these methods).

By addressing these hypotheses, the study aims to provide a comprehensive understanding of the factors influencing the adoption and implementation of active teaching methods and digital technologies in higher education.

MATERIALS AND METHODS

This study employed a mixed methods approach to investigate higher education students' perceptions of active teaching methods and digital integration. Quantitative survey data were combined with qualitative insights from open-ended questions to provide a comprehensive understanding of the training programme's impact. The sample consisted of 60 students from *L.N. Gumilyov* Eurasian National University, Astana, Kazakhstan, who had recently completed a computer science course, selected for convenience.

The training programme spanned eight weeks and included interactive workshops, hands-on sessions, collaborative activities and self-paced learning. The primary goals were to enhance students' understanding of active learning methodologies, such as CBL, TBL and PBL, and to improve their proficiency in using digital tools to support these methods. Collaborative learning was emphasised through peer reviews and group projects.

The programme was divided into four phases:

1. Weeks 1-2: introduction to active learning methods and their theoretical foundations through interactive lectures and discussions.
2. Weeks 3-4: hands-on workshops on creating case studies and problem scenarios, including group activities and peer reviews.
3. Weeks 5-6: training on digital tools and technologies, covering learning management systems (LMS), Web-based applications, multimedia resources and virtual classrooms.
4. Weeks 7-8: application and integration of active learning methods and digital tools, where participants developed lesson plans and conducted mock teaching sessions.

The programme was delivered in a hybrid format, combining in-person workshops at *L.N. Gumilyov* Eurasian National University in Astana, Kazakhstan, with on-line sessions facilitated through a learning management system (LMS). Programme effectiveness was assessed using pre- and post-training evaluations, participant feedback and peer reviews. Assessments focused on participants' knowledge, confidence, and ability to apply active learning methods and digital technologies.

Survey Instrument

The survey instrument was developed and refined through pilot testing to ensure validity and reliability (Cronbach's alpha = 0.85). Key survey questions are shown in Table 1.

Table 1: Survey questions for students.

Number	Questions	Response type
1	How effective do you find case-based learning (CBL) in enhancing your understanding of course concepts?	Rating scale 1-10
2	How effective do you find team-based learning (TBL) in improving collaboration with your peers?	Rating scale 1-10
3	How effective do you find problem-based learning (PBL) in developing your problem-solving skills?	Rating scale 1-10
4	Which method do you believe is most effective for developing critical thinking and problem-solving skills?	Multiple choice
5	What are the main challenges in using these methods?	Multiple choice
6	Do you feel you have sufficient resources and training to engage with these methods effectively?	Multiple choice
7	Did the training programme increase your confidence in using digital technologies in learning?	Yes/No
8	How would you rate your confidence in using digital technologies after the training programme?	Rating scale 1-10
9	To what extent do you agree that digital tools enhance the effectiveness of active teaching methods?	Likert scale

Data Analysis

Data were analysed using both thematic analysis and statistical tests. Descriptive statistics provided an overview of participant responses. Chi-square tests assessed associations between categorical variables, and ANOVA was conducted to compare mean effectiveness ratings across different groups.

Results

The results of this study are organised to address the research objectives and hypotheses. Each subsection covers a specific hypothesis supported by tables and graphs to provide a comprehensive understanding of the findings.

Hypothesis H_1: Effectiveness of Active Teaching Methods and Digital Technologies

The primary objective was to assess how higher education students perceive the effectiveness of active teaching methods (CBL, TBL and PBL) and digital technologies in enhancing student engagement and learning outcomes.

1. Responses to Question 1 (CBL effectiveness): the responses to the effectiveness of CBL methods showed high scores, with a mean of 7.9, a median of 8.0 and a standard deviation of 1.92 (see Table 2).
2. Responses to Question 2 (TBL effectiveness): the responses to the effectiveness of TBL methods showed a mean of 7.2, a median of 8.0 and a standard deviation of 2.36 (see Table 2).
3. Responses to Question 3 (PBL effectiveness): the effectiveness rating of PBL methods showed high scores, with a mean of 7.9, a median of 8.0 and a standard deviation of 1.92 (see Table 2).

Table 2: Frequency distribution of CBL effectiveness ratings.

Rating interval	CBL	TBL	PBL
1-3	5%	10%	5%
4-6	10%	20%	10%
7-9	60%	50%	60%
10	25%	20%	25%
Mean	7.90	7.20	7.90
Median	8.00	8.00	8.00
SD	1.92	2.36	1.92

The analysis reveals that active teaching methods are generally perceived positively by students. For CBL and PBL, 85% of responses fall within the 7-10 rating interval, indicating strong approval. TBL also received favourable ratings, with 70% of responses in the 7-10 range.

Responses to Question 4: in response to which method students believe is most effective for developing critical thinking and problem-solving skills, PBL was preferred by 31 students (52%), highlighting its prominence (see Figure 1). CBL was chosen by 18 students (30%), and TBL by 6 students (10%). Mixed methods were also noted, with a few students selecting combinations of methods (CPBL, CTPBL).

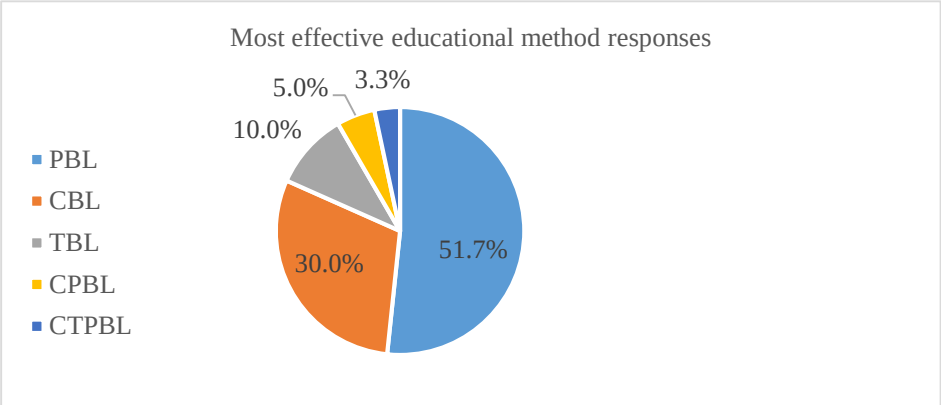

Figure 1: Perceptions of teaching method effectiveness (Question 4).

Pre- and Post-Training Assessments

The pre- and post-training assessments demonstrated significant improvements in participants' scores across three constructs: knowledge, confidence and practical application (see Table 3):

- Knowledge: mean score increased from 3.5 (SD = 1.0) pre-training to 7.8 (SD = 0.8) post-training, an improvement of 4.3 points.
- Confidence: mean score rose from 4.0 (SD = 1.2) to 8.2 (SD = 0.7), a 4.2 point increase.
- Practical application: mean score improved from 3.8 (SD = 1.1) to 8.0 (SD = 0.9), also a 4.2 point increase.

Table 3: Comparison of pre- and post-training assessment scores.

Construct	Pre-training mean (SD)	Post-training mean (SD)	Improvement
Knowledge	3.5 (1.0)	7.8 (0.8)	+4.3
Confidence	4.0 (1.2)	8.2 (0.7)	+4.2
Practical application	3.8 (1.1)	8.0 (0.9)	+4.2

Hypothesis H_2: Challenges in Implementing These Methods

The survey aimed to identify the main challenges faced by students in implementing active teaching methods (Figure 2):

- Lack of resources - cited by 26 students (43.3%) as a significant issue.
- Time constraints - reported by 20 students (33.3%) as a major hindrance.
- Evaluation difficulties - highlighted by 12 students (20.0%).

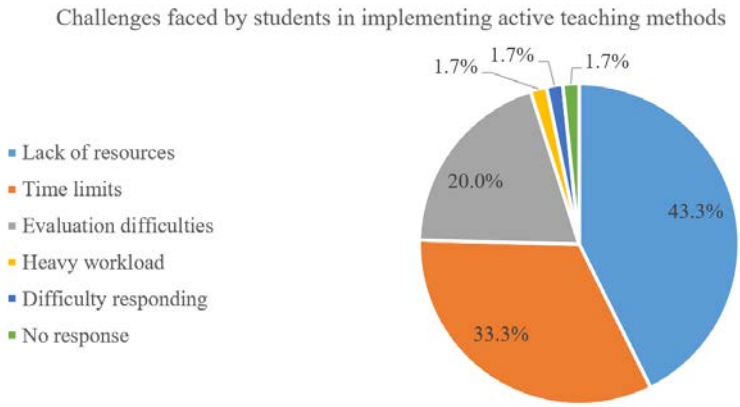

Figure 2: Challenges in implementing teaching methods (Question 5).

Feedback sessions and peer evaluations revealed that participants frequently mentioned resource limitations and time constraints as significant challenges in implementing active teaching methods. One participant noted: *While the training was excellent, applying these methods without sufficient resources is quite challenging*. Another echoed this sentiment, stating that: *The lack of time to properly plan and implement these methods is a major obstacle*. Peer evaluations highlighted similar concerns, with peers observing that while participants were enthusiastic and more confident after the training, they often struggled with the practical aspects of implementation due to resource and time constraints.

Statistical Analysis

To test H_1, the authors conducted an ANOVA test to determine whether students perceive CBL, TBL, PBL and digital technologies as effective across the entire sample. The null hypothesis (H_0) for this test was that students do not view these methods as effective. The results showed a significant difference in students' perceptions, with a *p*-value of 0.003, indicating that the null hypothesis was rejected. This suggests that students found these methods effective in enhancing engagement and learning outcomes.

For H_2, the authors examined whether resource scarcity and time constraints significantly challenge the implementation of these methods. The null hypothesis (H_0) was that resource scarcity and time constraints do not pose significant challenges. A chi-square test was conducted, revealing a *p*-value of 0.021, which is below the significance threshold of 0.05. Therefore, the null hypothesis was rejected, thus indicating that resource scarcity and time constraints were significant challenges for the effective implementation of CBL, TBL and PBL.

Additionally, a chi-square test was conducted to examine the relationship between students' semester and their perceptions of the effectiveness of CBL, TBL and PBL. This secondary analysis aimed to explore whether students' views varied across academic levels. The calculated chi-square statistic was 39.922, with a *p*-value of 0.999, which is well above the significance threshold of 0.05. Since the *p*-value is higher than the significance level, the authors failed to reject the null hypothesis, indicating that the students' views on the effectiveness of CBL, TBL and PBL do not vary meaningfully across semesters.

Implications for Study Hypotheses:

- Hypothesis H_1: Supported by the data, as students generally perceive active teaching methods and digital technologies as effective.
- Hypothesis H_2: Also supported, as significant challenges, such as lack of resources and time constraints were identified.

DISCUSSION

Hypothesis H_1: Effectiveness of Active Teaching Methods and Digital Technologies

The results from this study underscore a strong positive perception among students regarding the effectiveness of active teaching methods, such as CBL, PBL and TBL, as well as digital technologies in enhancing student engagement and learning outcomes. The null hypothesis H_0 was rejected, providing strong evidence of the perceived effectiveness of these teaching methods. According to the diffusion of innovations theory, innovations are more likely to be adopted if they are perceived as beneficial and compatible with existing practices [14]. The high effectiveness ratings suggest that these methods align well with students' learning preferences and educational needs, facilitating their adoption in higher education settings.

However, it is important to consider certain limitations that may have influenced these findings. The sample size was relatively small and drawn from a single institution, which may limit the generalisability of the results to the broader student population across different institutions and disciplines in Kazakhstan. Additionally, the use of convenience sampling could introduce selection bias, potentially overrepresenting students who are already inclined toward active learning methods. The self-reported nature of the survey responses may also be subject to social desirability bias, where students might overstate the effectiveness of active teaching methods and digital technologies to align with perceived expectations.

Despite these limitations, the findings are consistent with recent studies. For example, Barrows found that PBL significantly enhances critical thinking skills and promotes deeper understanding [15]. Similarly, Michaelsen et al demonstrated that TBL fosters collaborative learning and student engagement [3]. In the context of Kazakhstan, active learning methods can play a crucial role in meeting educational reform goals aimed at improving the quality of higher education and aligning it with international standards [16].

Hypothesis H_2: Challenges in Implementing These Methods

The data support also the alternative hypothesis H_2, as significant challenges related to resource scarcity and time constraints were identified. The authors rejected the null hypothesis H_0, confirming that these constraints significantly hinder the implementation of these methods. In a secondary analysis, the chi-square test showed no meaningful variation in students' perceptions across semesters. This result further emphasises the consistency of student perceptions regarding the effectiveness of CBL, TBL and PBL across different academic levels.

The lack of sufficient resources and the additional time required for planning and implementation can hinder the effective integration of these methods into educational programmes. It is noteworthy that the study did not extensively explore the specific nature of these resource limitations or how they might differ across various educational contexts.

Additionally, since the training programme was conducted over a relatively short period, participants may have experienced heightened time constraints, potentially influencing their perceptions of this challenge.

These limitations suggest that the challenges identified may be more pronounced than reported, emphasising the need for further investigation. Nonetheless, the issues highlighted are reflected in contemporary research. Ertmer and Ottenbreit-Leftwich emphasised the necessity of adequate resources and support for effective technology use in education [17]. In Kazakhstan, substantial investments in digital infrastructure and professional development for educators are essential to overcome these barriers and enhance the adoption of active teaching methods [18].

FUTURE RESEARCH DIRECTIONS

Future research should delve deeper into the specific aspects of active teaching methods and digital technologies that enhance student engagement and learning outcomes. For instance, studies could investigate the long-term impact of PBL on career readiness among computer science graduates, employing longitudinal designs to track students' performance and employment outcomes over time. Comparative studies across different disciplines and institutions could provide a more granular understanding of the effectiveness of CBL, PBL and TBL. Utilising larger, randomised samples would address current limitations related to sample size and representativeness, enhancing the generalisability of the findings. Research could also explore the specific resource limitations and time constraints that hinder the implementation of active teaching methods. Qualitative methodologies, such as interviews or focus groups with students and educators, might uncover detailed insights into these challenges.

Additionally, examining the role of institutional support and policy frameworks in facilitating or impeding the adoption of these methods would be valuable. By addressing these limitations, future studies can contribute to a more comprehensive understanding of how to effectively integrate active teaching methods and digital technologies in higher education. This would not only inform educational practices, but also aid in the development of policies aimed at improving the quality of higher education in Kazakhstan and similar contexts.

LIMITATIONS

This study has several limitations that should be considered when interpreting the results. First, the sample size, while sufficient for initial insights, may not fully represent the diverse student population across different institutions and disciplines in Kazakhstan. The use of convenience sampling could introduce selection bias, limiting the generalisability of the findings.

Additionally, the self-reported nature of the survey responses may be subject to social desirability bias, where students might overstate the effectiveness of active teaching methods and digital technologies. Furthermore, the study did not account for potential differences in the quality of implementation of these methods, which could significantly influence their perceived effectiveness. Future research should employ larger, randomised samples and consider using mixed method approaches to validate and extend these findings.

CONCLUSIONS

This study provides an exploratory examination of student perceptions of active teaching methods and digital technologies in higher education within Kazakhstan. The findings highlight the positive reception and perceived effectiveness of CBL, PBL and TBL in enhancing student engagement and learning outcomes. However, significant challenges related to resource limitations and time constraints were identified, underscoring the need for institutional support and investments in digital infrastructure.

While acknowledging limitations, such as sample size, sampling methods and potential biases, the study contributes valuable insights into the factors influencing the adoption and implementation of active teaching methods. These insights add to the ongoing discourse on educational reforms in Kazakhstan and provide a foundation for future research and policy development aimed at improving the quality of higher education.

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INSTITUTIONAL REVIEW BOARD STATEMENT

The semi-interview applied in this study was approved be the Ethical Commission of the NAO, *A. Margulan* Pavlodar Pedagogical University, dated 15.01.2024, under the approval code 1. Prior to participation, all participants were informed about the purpose of the study, the procedures involved, their rights as study participants, and the use of their data for research purposes. Informed consent was obtained from all individual participants included in the study.

DATA AVAILABILITY STATEMENT

All data supporting the findings of this study are openly available. The primary datasets analysed during the current study are available in the supplementary materials accompanying this article. Additional data and resources can be accessed through *A. Margulan* Pavlodar Pedagogical University, which hosts all relevant information and datasets necessary for replicating the results or extending the analysis.

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