Enhancing Conceptual Understanding in Data Science through Peer Instruction: An Empirical Study Using Poll Everywhere

Dr. Divya Mohan, Department of Computing Technologies, School of Computing, SRM Institute of Science and Technology, Kattankulathur, Chengalpattu, India-603203

Divya Mohan is an Assistant Professor in the Department of Computing Technologies at SRM Institute of Science and Technology, India. She completed her Ph.D. in Computer Science and Engineering from Vellore Institute of Technology. Her research interests span wireless network scheduling, soft computing, machine learning, and active learning strategies in computing education. She has authored multiple peer-reviewed journal and conference publications and actively integrates research-driven and student-centered pedagogies into her teaching practice. Dr. Mohan is particularly interested in applying artificial intelligence and data-driven approaches to enhance engineering education outcomes and learner engagement. She has participated in several faculty development programs and workshops focused on innovative teaching, curriculum design, and experiential learning. Her work aims to bridge the gap between emerging technologies and effective engineering education practices

Dr. Bhuvana Gopal, University of Nebraska - Lincoln

Dr. Bhuvaneswari (Bhuvana) Gopal is an Assistant Professor of Practice in the School of Computing at the University of Nebraska-Lincoln where she teaches Software Engineering, Software Security in Practice, the industry internship course, and leads the Learning Assistant Program that serves several computing courses at the School of Computing. Dr. Gopal has extensive experience in the software industry, where she spent 14 years in various roles, including Software Architect and Lead software engineer positions before switching to full time academia. She is also a Microsoft certified professional, with an MCPD certification. Her research work is focused on evidence-based, active learning pedagogies to improve software engineering education. She has published papers specifically on Peer Instruction and Process Oriented Guided Inquiry-based Learning-like pedagogical approaches in the undergraduate software engineering classroom, both in person and virtual. She holds a Bachelors degree in Physics from the University of Madras, Chennai, India. She holds two Masters degrees - one in Computer Science from the University of Nebraska-Lincoln, and one in Medical Physics from Anna University, Chennai, India. She holds a Ph.D. in Computer Science from the University of Nebraska-Lincoln.

Byrav Ramamurthy, University of Nebraska - Lincoln

Byrav Ramamurthy is currently a Professor in the Department of UNL School of Computing at the University of Nebraska-Lincoln (UNL). He is the author of the book ”Design of Optical WDM Networks - LAN, MAN and WAN Architectures” and a co-author of the book ”Secure Group Communications over Data Networks” published by Kluwer Academic Publishers/Springer in 2000 and 2004 respectively. He served as the Chair of the IEEE Communication Society's Optical Networking Technical Committee (ONTC) during 2009-2011. He served as the IEEE INFOCOM 2011 TPC Co-Chair. He is currently the Editor-in-Chief for the Springer Photonic Network Communications (PNET) journal.

His research areas include optical and wireless networks, peer-to-peer networks for multimedia streaming, network security and telecommunications. His research work is supported by the U.S. National Science Foundation, U.S. Department of Energy, U.S. Department of Agriculture, NASA, AT&T Corporation, Agilent Tech., Ciena, HP and OPNET Inc.

Enhancing Conceptual Understanding in Data Science through Peer Instruction: A Pilot Classroom Implementation Study Using Poll Everywhere

Abstract

In the dynamic landscape of STEM education, active learning strategies have become central to promoting student engagement, critical thinking, and long-term retention. This study investigates the application of Peer Instruction (PI) in a data science classroom, specifically within the module "Problems Faced When Handling Large Data & General Techniques for Handling Large Volume of Data." Sixteen third-year undergraduate students participated in a structured activity using the digital response system Poll Everywhere, where they responded to ten multiple-choice questions five targeting recall and five targeting conceptual understanding. Each question followed a three-step PI cycle: initial individual vote, peer discussion in groups of four, and a post-discussion vote. The learning gains were assessed using pre- and post-discussion accuracy. The average gain for conceptual questions was 21.8%, with the highest improvement seen in the CAP theorem question (+50%), followed by questions on MapReduce, caching, and batch processing. Recall-based questions saw an average gain of 17.6%, with notable improvement in the question related to Parquet file format (+56%), highlighting the effectiveness of PI even in knowledge recall under unfamiliar terminology. Informal oral reflections from students suggested increase in conceptual clarity, boosted confidence, and a clear preference for the collaborative approach. Students particularly valued peer explanations and reported that discussion made abstract content easier to understand. They expressed strong interest in adopting this model for future sessions. These findings suggest that when integrated with real-time polling tools, Peer Instruction is a highly effective pedagogical strategy for enhancing deep learning in data science education, especially for cognitively demanding topics. As a small-scale classroom pilot involving a single cohort (n = 16), the findings should be interpreted as preliminary evidence supporting the feasibility and potential effectiveness of Peer Instruction in data science education.

Introduction

The explosion of data in the modern digital era has revolutionized industries and transformed how we think about information. [1] To prepare students for real-world data challenges, data science education must evolve beyond rote memorization and superficial familiarity with tools [2]. It must enable learners to grasp complex, often abstract concepts such as distributed computing, consistency trade-offs, data scalability, and the mechanics of data pipelines. While lectures remain a foundational component of instructional delivery, they often fail to sufficiently engage students in meaningful learning processes [3]. A truly promising method of introducing deep learning and involvement in technical courses is that of Peer Instruction (PI). Based at initial in-services in physics teaching, PI has become a structured peer-to-peer discussion affair aimed at promoting conceptual thinking. The students are initially introduced to a question and ordered to vote as individuals, then they are asked to justify their choices to other students and finally they are requested to vote once again. This strategy does not only contribute to the emergence of misconceptions but also enables students to express their thinking mode which results in a greater understanding of knowledge.

This work will use the PI model to observe the effect it has on the learning process of complicated subjects in the field of data handling in a data science classroom. In particular, we discuss how it influences three kinds of learning outcomes, that is, factual recall, conceptual comprehension, and procedural application. Poll Everywhere is a real-time polling application which was employed to collect and analyze responses of students prior to peer discussion and after it.

Research Questions

The research questions that are primary that will be answered by the study are:

RQ1: How does Peer Instruction impact student learning performance for recall and conceptual questions?

RQ2: Which type of question (recall or conceptual) is perceived as more difficult by students?

RQ3: What are the pedagogical implications of using PI with digital polling tools in a data science context?

Literature Review

Active Learning in STEM Classrooms

STEM education is undergoing a pedagogical change, shifting from passive lectures to active learning techniques that emphasise student participation and interaction. STEM education highlights active learning and it decreases achievement gaps in exam division by 33 percent and decreases passing gap by 45 percent, particularly at high-intensity classes [4]. The more active learning within STEM education, the more learning of important 21st century skills and the more general satisfaction is linked to it [5].

Peer Instruction: A Proven Strategy

Peer Instruction (PI) has repeatedly proved to have beneficial effects on student learning since it enhances has improved their accuracy and confidence after the discussion with peers [6]. This methodology has been well researched and has proved to be relevant and applicable in many fields of study in the sphere of science, technology, engineering, and mathematics (STEM) [7]. Outside the remit of the technology-oriented fields, PI has been found to be useful too in the acquirement of writing skills in students with learning disabilities, developing their linguistic and collective skills as com-pared to control groups [8]. Being considered a known active learning technique, PI gives a chance to students to share ideas and work on them by improving their own knowledge, and at that, sometime can be left to instructor feedback and instruction [9].

In particular, in the undergraduate courses in software engineering, the use of PI has been associated with enhancement of student performance in the unit testing, integration testing, and continuous integrations [10]. In addition, this approach promotes meaningful learning, which gives students skills to solve new problems and use their knowledge in new and diverse areas [11].

Digital Polling and Classroom Technology

Slido is an online polling platform containing many advantages, as it substantially improves student engagement on difficult engineering modules, providing better learning results and a more pleasant learning experience [12]. Both low-tech and high-tech in-class polling systems are typically viewed by the students as a positive experience, and the advantages and disadvantages of each system will differ according to the implemented platform [13]. Participation and comfort in communicating in different contexts can be boosted by using the web-based polling sites such as Poll Everywhere, which would increase classroom participation and improve the outcomes of learning [14]. Poll Every-where is innovative and cheap enabling technology that improves the learning and the classroom environment of the students as well as the effectiveness of the instructors as they are better able to deliver and test course material [15].

Research Gaps and Study Motivation

Peer Instruction has been recognized to have its own positive aspect in the learning process of the students, engagement and motivation. Nonetheless, there is a number of severe research shortcomings especially with regard to the mechanism of motivation regulation, the context-specific success of the technique and the effect of individual learner variations. Indeed, these dimensions are still being researched as improvements on the outcomes of education are sought through successful collaborative learning strategies as well as research gaps on Peer Instruction being as indicated in Table 1. It has been demonstrated consistently that PI enhances accuracy and confidence as a result of experiencing peer discussions, and the social learning processes and the coherence of peer explanations have become major factors in the determination of these improvements [16]. Research experiments are currently being conducted to decipher the influence of peer relationships and classroom atmosphere in assisting or strangling motivation and development of ideas and concepts [17]. Moreover, researchers pay more and more attention to the way of defining specific strategies to accommodate different student profiles and maximize the usage of PI in different areas of education and various learning conditions [18].

Table 1. Research Gaps in Peer Instruction Learning

Identified Gaps	Description
Mechanisms of Motivation Regulation	Limited evidence on how students actively regulate each other's motivation during peer instruction and collaborative learning
Context-Specific Dynamics	Need for more research on how peer instruction impacts motivation in different disciplines, educational levels, and cultural contexts
Longitudinal and Causal Evidence	Few studies use longitudinal or experimental designs to establish causality between peer instruction, motivation, and achievement

Individual Differences	More research needed on how personality, prior achievement, and motivation influence who benefits most from peer instruction

Methodology

Participants and Settings

The research was done in Undergraduate data science course of the third year of a private Indian university. Voluntary participants in the activity were 16 in number. In order to stimulate effective communication between the peers, the students were split into four groups four students each. These teams were balanced regarding grades and the variety of opinions, which encouraged equal participation in a discussion.

Instructional Design

The instructional intervention was designed around the topic "Problems Faced When Handling Large Data & General Techniques for Handling Large Volume of Data." A total of 10 multiple-choice questions (MCQs) were selected and classified based on cognitive difficulty into two categories:

- **Recall** (Questions 1–5): Targeting basic factual knowledge (e.g., definitions, terminology, and common tools), given in Table 2.
- **Conceptual** (Questions 6–10): Focused on understanding relationships, theoretical trade-offs, and abstract models (e.g., CAP theorem, caching), given in Table 3.

Instructional Sequence

The Peer Instruction cycle was conducted as follows:

- **Pre-discussion Vote:** Students answered each question independently using Poll Everywhere.
- **Peer Discussion:** Groups discussed the question for 5-7 minutes, exploring reasoning and justifications.
- **Post-discussion Vote:** Students answered again individually.

Data Collection and Tools

All responses were recorded in Poll Everywhere and analysed to assess:

- **Quantitative:** Accuracy of pre- and post-discussion answers was logged.
- **Perception Poll:** A dedicated Poll Everywhere question asked: *"Which type of question was more difficult for answering?"*
- **Qualitative Feedback Collection:** Informal oral feedback was collected at the end of the session through open classroom discussion. No structured interview protocol or thematic coding was applied; responses were recorded as observational reflections to supplement quantitative findings.

Table 2. Recall Multiple-Choice Questions Used in Peer Instruction Session with Correct Answers

Q.no	Question	Options	Correct Answer
Q1	Which of the following is NOT a common challenge in handling large data?	a) Storage limitations b) Slow processing speed c) Increased accuracy d) Data inconsistency	c)Increased accuracy
Q2	What is the primary purpose of data compression?	a) Reduce storage b) Improve accuracy c) Enhance redundancy d) Increase corruption	a) Reduce storage
Q3	Which technique improves performance for large datasets?	a) Encryption b) Indexing c) Replication d) Duplication	b) Indexing
Q4	What is breaking down a large dataset into parts called?	a) Sharding b) Mining c) Encryption d) Redundancy	a) Sharding
Q5	Best file format for storing large structured data?	a) CSV b) JSON c) XML d) Parquet	d) Parquet

Table 3. Conceptual Multiple-Choice Questions Used in Peer Instruction Session with Correct Answers

Q.no	Question	Options	Correct Answer
Q1	How does distributed computing help?	a) Use one machine b) Distribute computation c) Reduce computations d) Avoid indexing	b) Distribute computation
Q2	What does the CAP theorem imply?	a) Get all three (C, A, P) b) Choose 2 of 3 c) Prioritize P d) Use centralized DB	b) Choose 2 of 3
Q3	What is the role of caching?	a) Store data permanently b) Fast access to frequent data c) Replace DB d) Remove redundancy	b) Fast access to frequent data
Q4	Advantage of batch processing?	a) Reduces latency b) Efficient large processing c) Immediate access d) Removes redundancy	b) Efficient large processing
Q5	Purpose of MapReduce?	a) Compress data b) Parallel data processing c)Transform structured data d) Avoid indexing	b) Parallel data processing

Results

Student Perception of Difficulty

To complement the quantitative performance data, a key component of this study involved capturing students' subjective experiences regarding the perceived difficulty of different question types. After completing all ten multiple-choice questions (five recall-based and five conceptual), students were presented with a final poll via Poll Everywhere that asked:

"Which type of question was more difficult for answering?"

- Recall Questions
- Conceptual Questions

The responses to this question offer important insight into students' cognitive engagement and the instructional demands of each question type. The results are tabulated in Table 4.

Table 4. Student Perception on Question Difficulty

Question Type	Percentage of Students Who Found It More Difficult
Recall Questions	25 %
Conceptual Questions	75 %

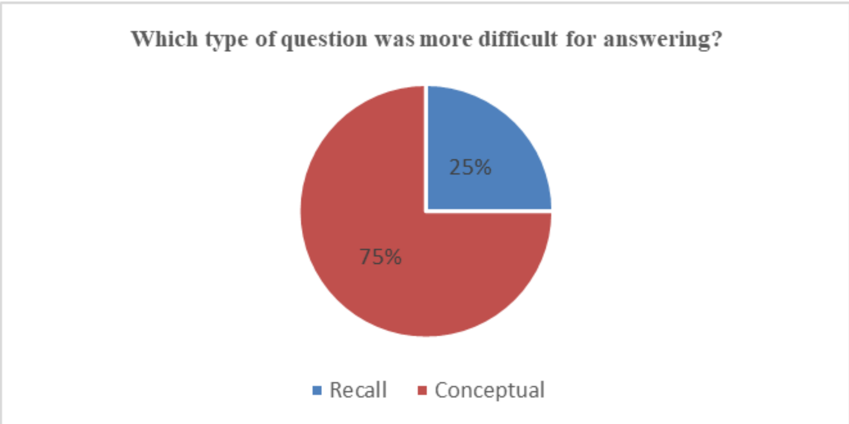

Figure 1. Cognitive Load Awareness from Student Perceptions

This Figure reveal a clear and significant trend in how students experience different cognitive tasks (see Fig). A majority of 75% indicated that conceptual questions were more challenging to answer. This is consistent with the design of these questions, which required not just factual recall but higher-order thinking such as reasoning, system understanding, and interpretation of abstract principles. In contrast, only 25% of the students found recall-based questions difficult, suggesting that these were either already well-known or easily deduced from prior knowledge or coursework. These reflections underscore that conceptual questions introduced an element of productive struggle, a vital component of deeper learning. Furthermore, the very act of articulating one's reasoning during peer discussion appears to have helped many students resolve conceptual confusion. The Poll Everywhere perception poll thus served as a diagnostic tool that helped instructors identify zones of difficulty and learning potential. These insights inform instructional design by highlighting where peer instruction is not just useful but essential.

In summary, this perception-based poll data confirms that:

- Students are aware of the cognitive demands of different question types.
- Conceptual questions require and benefit from deeper engagement.
- Peer discussions are especially valuable when confronting conceptual ambiguity.

These findings strongly justify the focused application of Peer Instruction to conceptual learning targets in data science and other technical disciplines.

Learning Gain (Pre vs. Post Peer Discussion)

The resulting learning gains were measured with pre-and-post Poll Everywhere responses to the peer instruction step. The Table 5 summarizes the student performance based on ten questions of recall and conceptual types. The average gain by the recall questions was +17.6 and the conceptual questions displayed the higher average gain of +21.8. The extraordinary increase in performance was observed in Q5 (Recall) with its 56% boost, which implies that even simple question types, such as recall-based ones, can considerably thrive under the discussion condition when the vocabulary of the questions is new (i.e., the term Parquet file format will be new). Two conceptual questions registered the greatest gain (Q7: CAP theorem, +50%) which suggests how arduous the task and influential the effect of resolving theoretical models can be as a result of peer interaction. The overall positive trend in all items will support the worth of the three-step PI model based on individual thinking, peer discussion, and solution. High post-scores compared to low pre-scores in questions that had moderate pre-scoring (Q9, Q10) indicate that most students did not have an initial clarity but conceptual clarity was found by students through collaborative thinking process.

Importantly, the observed trend also aligns with cognitive learning theory students gain more from discussions where there is conceptual disequilibrium, and this is more often the case in conceptual questions. The findings support the adoption of Peer Instruction as an inclusive and dialogic teaching strategy to enhance deep learning in data science, especially in courses dealing with distributed systems, architecture constraints, and high-volume data processing paradigms. The consistent improvement across all items supports the effectiveness of the structured PI cycle. of the whole items reaffirm the worth of the three-step PI model of independence thinking, peer discussion and closure. Questions with moderate pre-discussion accuracy but high post-discussion gains (e.g., Q9, Q10) indicate that peer dialogue helped resolve conceptual ambiguity. This pattern aligns with cognitive learning theory, which suggests that conceptual conflict can stimulate deeper understanding. The results support the use of Peer Instruct as a teaching methodology, which is inclusive and dialogic in nature, with a view to facilitating deep learning in data science and particularly to those courses involving distributed systems, architectural limitations, and paradigms of mass volume of data processing.

Discussion and Pedagogical Implications

This Study highlights the pedagogical usefulness of Peer Instruction (PI) in fostering deep learning in training data science. The gradual rise in post-discussion results confirms the idea that in the conditions of regulated peer activities essential not only to correct the misconception is developing but also to form the clarity of ideas and preferential cognitive rearrangements. The prominent result was the substantial upsurge in the number of conceptual questions, whereby an improvement of 50 percent was achieved concerning the CAP theorem (Q7). What this indicates is that abstract questions that require thinking about systems and tradeoffs are greatly aided by peer explanation and reiterative reasoning that is commonly constrained in lectures-based styles. Teaching-wise, such findings make the need to incorporate PI clear, as demonstrated by helping foster metacognition and involvement in active learning, especially in complicated, abstract subjects where mere memorization and recall is not enough. Integration of PI in the data science curriculum can help in long-term retentions and further comprehension.

Table 5. Pre and Post Discussion Scores for Recall and Conceptual Questions with Learning Gain

Q.no	Question Type	Question Focus	Correct Option Summary	Pre (%)	Post (%)	Gain (%)
Q1	Recall	Data challenges	Increased accuracy	86%	94%	+8%
Q2	Recall	Purpose of data compression	To reduce storage requirements	83%	88%	+5%
Q3	Recall	Database performance	Data indexing	88%	100%	+12%
Q4	Recall	Dataset partitioning	Data sharding	89%	96%	+7%
Q5	Recall	Efficient file format	Parquet	19%	75%	+56%
Q6	Conceptual	Distributed computing	Distributing data and computation across multiple machines	86%	100%	+14%
Q7	Conceptual	CAP theorem	You can only choose two out of consistency, availability, and partition tolerance	50%	100%	+50%
Q8	Conceptual	Role of caching	Speeds up retrieval using memory	94%	100%	+6%
Q9	Conceptual	Batch vs. real-time	Batch improves efficiency	75%	100%	+25%
Q10	Conceptual	Purpose of MapReduce	Parallelize and distribute processing	86%	100%	+14%

The employment of Poll Everywhere also served two purposes as an engagement and formative assessment tool. Its anonymity favoured the truth and participation, whereas real-time feedback assisted teachers to promptly recognize and eliminate misconceptions. The anonymity of Poll Everywhere appeared to encourage broader participation during voting phases. However, this study did not formally measure participation equity or demographic differences. Future research should examine how Peer Instruction influences engagement patterns across diverse student populations. Self-efficacy was also supported and the students were less hesitant to tackle the technical subjects as also other students talked about them. Teachers witnessed a greater freedom of communication and respect and a collaborative culture of academic work. To apply it in the future, it is possible to enlarge PI with problem-solving assignments, coding exercises, or mini-design sprints that focus on higher-order thinking. The heterogeneous group formation (by skill or experience) might also increase the peer learning out-comes.

Limitations of the Study

This study provides encouraging evidence for the effectiveness of Peer Instruction (PI) in enhancing conceptual understanding in data science, several limitations must be acknowledged:

- **Limited Sample Size**:
  The study involved only 16 students from a single cohort, restricting the generalizability of the results to broader populations.

- **Topic-Specific Focus**:
  The intervention targeted a narrow topic "Problems Faced When Handling Large Data" which may limit applicability across the wider data science curriculum, especially in mathematically intensive areas.

- **Assessment Constraints**:
  Reliance on multiple-choice questions, though structured across recall and conceptual levels, may not capture higher-order thinking or long-term understanding. Alternative formats like open-ended questions or coding tasks could provide deeper insights.

- **Unstructured Peer Discussions**:
  Informal and unguided group interactions may have led to variability in discussion quality and learning outcomes.

- **Technology-Related Bias**:
  Use of Poll Everywhere, while effective for real-time engagement, may have posed challenges for students less comfortable with digital tools.

These limitations highlight opportunities for future research, including larger and more diverse samples, broader topic coverage, mixed-method assessments, and structured facilitation of peer interactions. Given the exploratory nature of this pilot implementation, causal claims cannot be established. The findings indicate trends rather than statistically generalizable effects.

Conclusion and Future Work

This study investigated the impact of Peer Instruction (PI) on student understanding in a data science module, specifically comparing performance and perception across recall and conceptual questions. The results provide preliminary evidence suggesting that PI may enhance conceptual comprehension in small-group data science settings.

- In response to RQ1 (*How does PI impact performance on recall vs. conceptual questions?*), findings showed that while both question types improved after peer discussion, Conceptual questions exhibited a greater average learning gain (+21.8%) compared to recall questions (+17.6%), calculated as absolute percentage-point improvement between pre- and post-discussion responses. This suggests that PI is particularly effective in supporting higher-order thinking.

- Regarding RQ2 (*Which question type is perceived as more difficult?*), the Poll Everywhere perception poll clearly revealed that 75% of students found conceptual questions more difficult, confirming the cognitive complexity of these tasks and the necessity for collaborative reasoning to resolve them.

- Addressing RQ3 (*What are the pedagogical implications of using PI in data science?*), student reflections and performance gains underscore the value of integrating PI into technical instruction. Students not only performed better post-discussion but also demonstrated increased confidence, engagement, and conceptual clarity through peer interaction.

This fact supports the finding that PI has the potential to fill this divide between recalling information on a sur-face-level and a more conceptual level of learning. Future research will seek to use the framework over diverse issues in data science, increase the sample size, and review longer-term knowledge retention. Incorporating procedural and problem-solving questions together with systematic peer feedback will improve on the instructional design and learning further.

References

1. Schell, J. A., Butler, A. C.: Insights from the Science of Learning Can Inform Evidence-Based Implementation of Peer Instruction. Frontiers in Education **3**(1), 01–13 (2018). https://doi.org/10.3389/feduc.2018.00033
2. Figueiredo, A. P. S., Figueiredo, N.: A quantitative analysis of the interaction among students in peer instruction classes. European Journal of Physics **41**(1), 0157030-01–12 (2019). https://doi.org/10.1088/1361-6404/ab497b
3. Da Costa Junior, M. G., Carvalho, A. A. A.: Reactions of Computer Science Students to Peer Instruction Activities in Class. In: 2022 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE) (2022): pp. 661–664. IEEE, (2022). https://doi.org/10.1109/TALE54877.2022.00112.
4. Theobald, E.J., Hill, M.J., Tran, E., Agrawal, S., Arroyo, E.N., Behling, S., Chambwe, N., Cintrón, D.L., Cooper, J.D., Dunster, G., Grummer, J.A.: Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. Proceedings of the National Academy of Sciences of the United States of America, **117**(2). 6476 – 6483, (2020).https://doi.org/10.1073/pnas.1916903117.
5. Ram, I., Rosenberg-Kima, R., Lewin, D.R., Barzilai, A., Chumtonov, O., Roll, I.: Active learning and the development of 21st century skills in online STEM education – a large-scale survey. Online Learning, **29**(1), 4-29 (2025). https://doi.org/10.24059/olj.v29i1.3533.
6. Tullis, J.G., Goldstone, R.L.: Why does peer instruction benefit student learning?Cognitive Research: Principles and Implications, **5**(1), 01–13 (2020). https://doi.org/10.1186/s41235-020-00218-5.

7. Stains, M., Vickrey, T., Rosploch, K., Rahmanian, R., Pilarz, M.: Research-Based Implementation of Peer Instruction: A Literature Review. CBE Life Sciences Education, **14**(1), 01–12 (2015). https://doi.org/10.1187/cbe.14-11-0198.
8. Khasawneh, Y.J.A., Khasawneh, M. A. S.: The Effectiveness of the Peer Education Strategy in Developing Writing Skills for Students with Learning Disabilities. Journal of Educational and Social Research **15**(3), 108–121 (2025). https://doi.org/10.36941/jesr-2025-0085.
9. Knight, J.K., Brame, C.J.: Peer Instruction. CBE Life Sciences Education, **17**(2), 1–4 (2018). https://doi.org/10.1187/cbe.18-02-0025.
10. Gopal, B. and Cooper, S.: Peer Instruction in Software Testing and Continuous Integration. In: Proceedings of the 52nd ACM Technical Symposium on Computer Science Education, pp. 548–554. ACM, USA (2021). https://doi.org/10.1145/3408877.3432404.
11. Cortright, R.N., Collins, H.L., DiCarlo, S.E.: Peer instruction enhanced meaningful learning: ability to solve novel problems. Advances in physiology education, **29**(2), 107–111 (2005). https://doi.org/10.1152/ADVAN.00060.2004.
12. Malekjafarian, A., Gordan, M.: On the Use of an Online Polling Platform for Enhancing Student Engagement in an Engineering Module. Education Sciences **14**(5), 536:1–23 (2024). https://doi.org/10.3390/educsci14050536.
13. Mendez, J.: Instructor and Student Experiences with In-Class Polling Options. ASEE IL-IN Section Conference, **3**, (2019). https://doi.org/10.5703/1288284316913.
14. Anderson, C.J.E.: Repurposing Digital Devices: Using Web-based Polling Sites as Vehicles for Classroom Participation. Journal of Teaching and Learning with Technology *7*(1), 152–156 (2018). https://doi.org/10.14434/JOTLT.V7I1.20147.
15. Shon, H., Smith, L.: A Review of Poll Everywhere Audience Response System. Journal of Technology in Human Services **29**(3), 236–245 (2011). https://doi.org/10.1080/15228835.2011.616475.
16. Järvenoja, H., Törmänen, T., Lehtoaho, E., Turunen, M., Suoraniemi, J., Edwards, J.: Investigating peer influence on collaborative group members' motivation through the lens of socially shared regulation of learning. The British journal of educational psychology **1**(1), 01–17 (2025). https://doi.org/10.1111/bjep.12754.
17. Ganotice Jr, F.A., Mendoza, N.B., Dizon, J.I.W.T., Shen, X., Lee, J.C.Y., Chan, E., Luk, P., Manio, M.M., He, Q., Khoo, U.S., Lam, M.P.: Students' motivation and engagement in interprofessional education: the mediating role of peer relatedness. Medical Education Online **29**(1), 2430593:1–12 (2024). https://doi.org/10.1080/10872981.2024.2430593.
18. Tu, J.-C., Chu, K.-H.: Analyzing the Relevance of Peer Relationship, Learning Motivation, and Learning Effectiveness—Design Students as an Example. Sustainability **12**(10), 4061:1–26 (2020). https://doi.org/10.3390/su12104061.