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REVIEW

Facilitating Active Collaborative Learning in Medical Education; a Literature Review of Peer Instruction Method

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Abstract: The call for educational reform by the Carnegie Foundation for the Advancement of Teaching marked a pivotal juncture in the trajectory of medical education in the United States. The call underscored the imperative for educational restructuring to equip forthcoming physicians with the requisite skills to engage in lifelong learning. Among the several active teaching methods is the Peer Instruction (PI), a brainchild of Eric Mazur, empowering students to steer their own education and wield knowledge adeptly into real-world scenarios. In this review paper, we delve into the core elements of PI which involves the combination of four dynamic pedagogical approaches which are: Just-in-Time Teaching, ConcepTest, Audience Response System, and Think-Pair-Share technique. PIs effectiveness notwithstanding, it is not exempt from limitations such as its flexible implementation, lengthy time, the level of expertise required for instructional design, among others. While Peer Instruction has become increasingly popular among educators across other disciplines, with proven educational benefits with positive outcomes, PIs footprint in gradate and postgraduate medical education remains inchoate, evidenced by a paucity of scholarly references. This underscores a crucial gap - despite its proven potency in fueling engagement and learning, PI still lacks formal recognition and acknowledgement as a distinct instructional method in medical education. Within these boundaries, the promise of heightened education and amplified engagement beckons further exploration of PI as a medical educational model, warranting more consideration and research.

Keywords: peer instruction, medical education, just-in-time teaching, ConcepTest, audience response system, think-pair-share

Introduction

In the past, traditional medical education has primarily relied on in-person classroom lectures and textbooks to convey information to students. While the educational character of all other science fields over the years appeared to transition from passive to more active means of teaching steadily, medical education seemed more rigid and reluctant to adopt such changes. The 2010 publication of "Educating Physicians: A Call for Reform of Medical School and Residency"[1] was very important in the history of United States medical education.[2] This report highlighted the need for educational reform to prepare future physicians with the required skills to engage in lifelong learning.[1,2] As a result, medical education implemented several changes to facilitate a learner-centered approach and promote active engagement and collaborative learning for students. Several medical curricula started adopting active learning methods, such as case-based learning, team-based learning, problem-based learning, and Peer-Instruction, which enabled students to take an active role in their learning process and encouraged them to apply their knowledge to real-world situations by enhancing their critical thinking, problem-solving, and clinical reasoning skills.[2]

One collaborative and active educational approach has been the Peer-Instruction (PI) method which has been employed with great success in the fields of science, technology, engineering, and mathematics (STEM) for several

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decades.[2–4] PI involves students working in small groups to engage with course material through active discussion and collaboration, focusing on peer-to-peer teaching and learning. This method has been shown to increase student engagement, participation, and knowledge retention and is a popular choice for instructors looking to promote active understanding.[2–4]

Despite its proven efficacy in STEM fields, PI has been underutilized in medical education, as evidenced by the limited body of research on this matter.[2] Incorporating PI in medical education could significantly enhance the learning experience for medical students, potentially leading to better outcomes for both students and patients. With the increasing recognition of the importance of active learning in medical education, there is a growing interest in exploring the potential of PI to enhance the learning experience for medical students. In this review, we explore the "PI" method and its potential application to graduate and post-graduate medical education.

Method

With the background knowledge that Mazur conceptualized Peer Instruction in 1997. For the first part of the paper, studies that investigated the use of peer instruction in STEM college courses were included. Using PubMed database from 1997 to 2023, we inserted the keywords "peer instruction" plus "STEM" this yielded a total of 65 papers. For the second part of the paper, we included studies that investigated the use of peer instruction in medical education. Using the keywords "peer instruction" plus "medical education", further filtered by article types to include books and documents, classical article, meta-analysis, randomized control trial, review, and systematic review, this yielded a total of 486 papers. These papers were then screened to exclude studies that did not follow the Mazur format of Peer Instruction; studies on Peer Assisted Learning (PAL), Peer teaching, Near-peer teaching, and Peer tutoring were all excluded. Similar search and filter were applied to Google Scholar database. In all, we selected a total of 44 most suitable literature for this study.

What is Peer Instruction?

Peer Instruction (PI) was first conceptualized by Eric Mazur, a physicist at Harvard University in 1991, who applied it as a method of teaching and learning to his undergraduate physics classes. PI's framework was based on the instructor posing conceptual questions (also referred to as ConcepTests) with discrete multiple-choice options and allowing students to think and record their answers individually, using an Audience Response System (ARS) or "clickers" as they are often called. Afterward, students engaged in discussions with their peers, explaining their reasoning, before voting again (also called Think-Pair-Share). The instructor then led a discussion of the correct answer, often seeking input from the class (Figure 1).[2,5–7]

Mazur created Peer Instruction intending to address the deficiencies in students' conceptual understanding that arise from passive learning experiences and an overreliance on traditional teaching models that prioritize the transmission of information. He believed that students needed to be more actively engaged in learning to develop a deeper understanding of the material.[5] By encouraging students to work together to solve problems and discuss concepts, Mazur aimed to create a more interactive and collaborative learning experience that would allow students to develop their critical thinking and problem-solving skills. Ultimately, Mazur's approach was designed to help students become more effective learners, better equipped to apply their knowledge in real-world situations.[5,7,8]

Popularization of Peer Instruction in STEM

To determine the efficacy of Peer Instruction, Dr. Mazur designed and administered various standardized tests in his physics course that assessed students' conceptual understanding. Results from his first standardized test showed an improvement in scores between the start of the physics class and two months after the class began when Peer Instruction was used.[5] Furthermore, the increase in scores on these tests was more significant than the traditional teaching methods, such as lectures, were used. A second standardized examination incorporating conceptual and computational questions again showed improvement in the average scores achieved by students taught using Peer Instruction compared with those prepared using traditional methods. The results from these two standardized examinations, combined with results from the same final examinations given by Dr. Mazur in 1985 using conventional teaching and in 1991 using Peer Instruction,

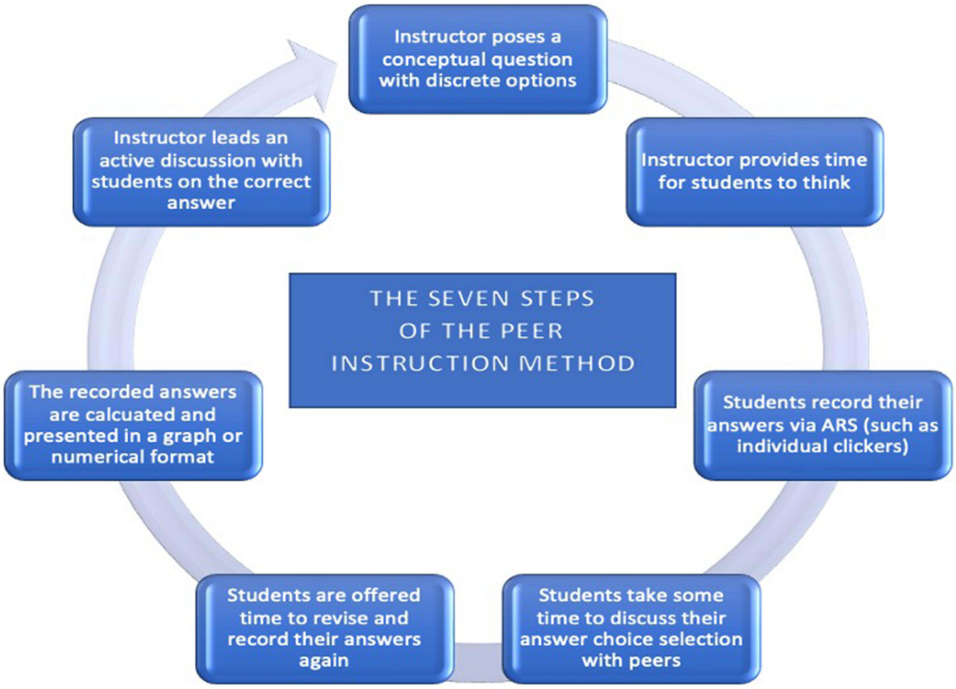

Figure 1 The seven steps of the Peer Instruction Workflow. Audience Response System (ARS).

indicated that Peer Instruction not only enhanced students' conceptual knowledge of physics but also provided them with better problem-solving abilities.[5] A longitudinal review by Crouch and Mazur, conducted ten years after the introduction of the Peer Instruction (PI) method to Harvard Physics classes, found that student performance, as measured by standardized assessments, improved compared with previous versions using the traditional didactic methods (TDL).[8] A global survey by Fagen evaluated users' experiences with Peer Instruction (PI). The results showed that most PI courses surveyed resulted in higher learning gains than traditional teaching methods and were consistent with interactive engagement. Additionally, over 80% of the instructors surveyed (more than 300) considered their use of PI successful. Furthermore, 90% of those surveyed who used the method planned to continue or expand their use of PI.[9]

Since its introduction, Peer Instruction (PI) has been the subject of numerous studies by education researchers, who have examined its effectiveness, implementation, and outlooks of both instructors and students.[2] Overall, an extensive literature review conducted by Vickey indicated that replacing traditional didactic lectures (TDL) with a Peer Instruction-based classroom has been found to enhance students' conceptual understanding, enhance qualitative and non-qualitative problem-solving skills, decrease student dropout rates, lower failure rates, and improve students' attitudes towards their classmates, instructors, and course.[2] Moreover, several recent studies have showcased how PI, when compared with TDL is significantly greater in improving attendance and enhancing student engagement.[4,6–8]

Pedagogical Elements in Peer Instruction Design

According to Knight et al, PI combines several pedagogical elements that are known to improve learning.[4] Peer instruction is a dynamic form of cooperative learning which has been found to raise student achievement, motivation, and positive attitudes toward science.[10] Furthermore, PI provides opportunities for students to explain their reasoning and engage in argumentation, which helps integrate new information with existing knowledge and improves mental models.[11] More specifically, Peer Instruction's successful implementation and positive results stem from its clever combination of four active learning methods: (a) Just-in-Time Teaching, (b) ConcepTest, (c) Audience Response System, (d) Think-Pair-Share technique.

Just-in-Time Teaching (JiTT)

Just-in-Time Teaching (JiTT) is a teaching and learning approach to foster an active learning environment during class. It was initially conceptualized by Gregor Novak and his team, who believed in creating a feedback loop between web-based learning materials and the classroom environment that could ultimately allow students to come prepared, motivated, and engaged in class.[12]

In JiTT, instructors use the Internet to upload course materials and pre-class reading in the form of Web-based Warm Up assignments, while students use these resources online to prepare for each class. The instructors then can leverage the student responses to identify areas of understanding and misunderstanding and adjust the lessons so that students can receive specific "just-in-time" feedback on those particular areas. JiTT empowers students to take more responsibility for learning the content outside of class in a more engaging and modern way than the conventional method of pre-class assigned textbook reading, optimizes class time for focused and impactful content explanations, and increases opportunities for interaction and discussion.[12]

According to Watkins and Mazur, PI is most successful when combined with Just-in-Time Teaching (JiTT),[5] summarized in Figure 2. JiTT prepares students for PI takes place and provides feedback to the instructor, enabling them to craft PI questions that address students' specific difficulties. Independently, both JiTT and PI offer valuable learning feedback to students at various stages - JiTT operates asynchronously outside of class, while PI provides immediate feedback during class. Combining these methods allows students and instructors to monitor learning progress in real-time, amplifying the benefits of the feedback.[13]

ConcepTests

Conceptual questions, or Concept Tests (ConcepTests), are crucial to the Peer Instruction (PI) method. These tests evaluate students' understanding of the key concepts taught and serve as a formative assessment tool for instructors to identify areas that require additional instruction. Unlike traditional STEM questions, ConcepTests can be answered based solely on the knowledge of relevant concepts without complex numerical calculations. The questions are usually multiple-choice and are easy to administer during in-class discussions with the help of an audience response system.[5]

However, ConcepTests are flexible and can be modified by instructors to meet the classroom's needs. The format and content of these tests can vary, such as being based on applications, case studies, or procedures. Alternatively, they may

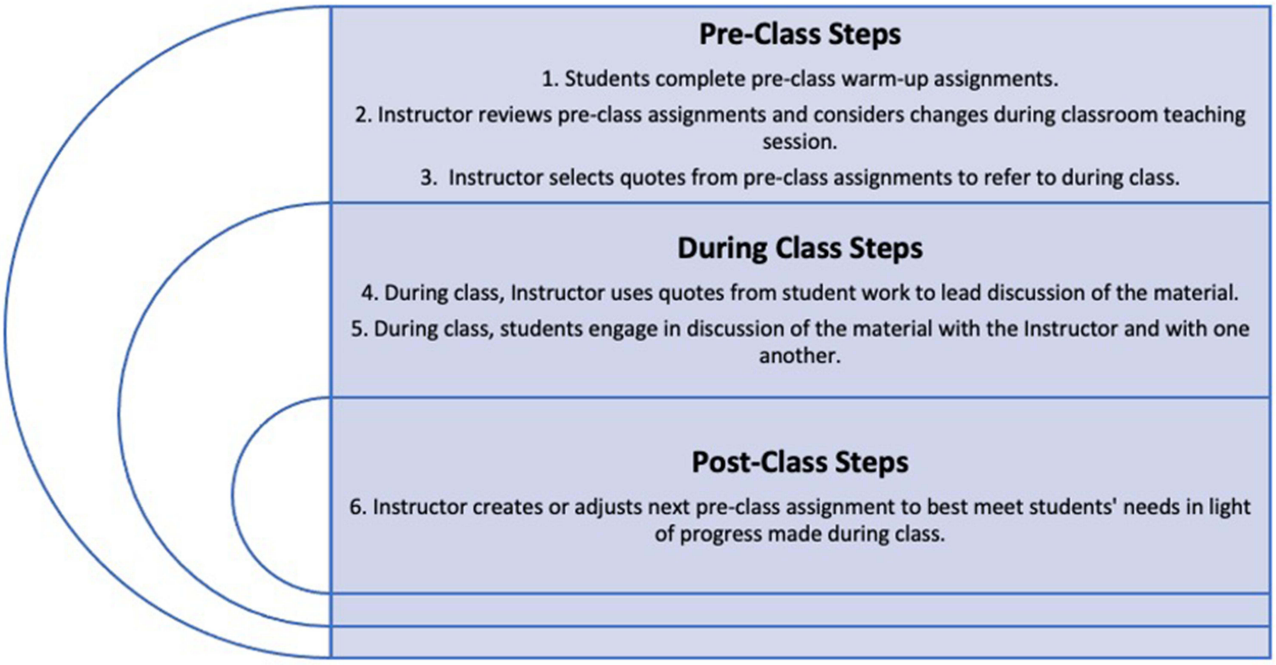

Figure 2 Just-in-Time Methodology; pre-class, during class, and post-class steps.

consist of logistical, recall, or algorithmic questions rather than conceptual ones. The format of the questions can also vary. At the same time, multiple-choice with one best answer is typical; other forms such as multiple true-false and free-response questions, or questions that encourage drawing, can also provide benefits.[4,14]

The goal of administering ConcepTests before and after group work is to enhance student engagement and learning. Research shows that ConcepTests in PI increase student learning, critical thinking, problem-solving skills, motivation, and attention compared with traditional lecture-based teaching methods.[4,5] Additionally, these tests provide immediate feedback on learning and allow students to track their progress over time.[4,5] Moreover, ConcepTests results can shape the instruction session's course. For example, according to researchers, ConcepTests with an initial correct response rate of 35% to 70% lead to the highest degree of engagement and most effective small-group discussions. If less than 35% of students answer correctly, the question may be too difficult, while more than 70% of correct response suggests that the instructor can move on to the next topic (See Figure 3).[4,5]

The outcomes of Peer Instruction largely depend on how well the Concept Tests is formulated. After the popularization of Concept Tests by Eric Mazur, and their widespread use in various subjects, studies have provided clear guidelines to instructors for efficient design of the ConcepTests for their Peer Instruction as shown in Figure 3. According to Knight and Zingaro, the questions should be engaging and challenging enough to provoke discussion.[15,16] The difficulty of the questions is only partially determined by the level of cognitive activity required to answer them. Sometimes, questions that need lower-order cognitive skills can generate robust peer discussions as much as those that require higher-order skills.[15] Furthermore, questions that address misconceptions can be especially beneficial,[17] as they expose students to a commonly held incorrect idea and allow them to understand why it is wrong.

Audience Response System

An audience response system (ARS) is a technology-based tool used across educational facilities since the 1960s and has become an integral part of the Peer Instruction method.[5] The audience response system allows the educator to pose multiple choice or true/false questions to the students, who then respond using handheld devices (known as "clickers") or, nowadays, more commonly used smartphone applications. The answers are then collected via the system and displayed in real-time on a screen, usually depicted as a histogram, providing immediate feedback to the students and the educator. In Peer Instruction, ARS assesses student understanding and engages them in learning.[5] By offering all students the chance to participate and respond to questions while allowing them to view the results of their peers' answers, ARS promotes active learning and helps to facilitate discussion and debate among the students.[6] ARS has also been found to enhance student class attendance.[6,18] At the same time, for educators, the higher-technology response systems allow for the analysis of student responses and progress, which can inform future teaching and assessment planning based on patterns of answer choices and can aid educators in adjusting their teaching method accordingly.[6,7,19]

Other methods, such as raising hands or using response cards to record student answers, have also been used along with Peer Instruction, with some researchers arguing that the method by which students indicate their answers is not of

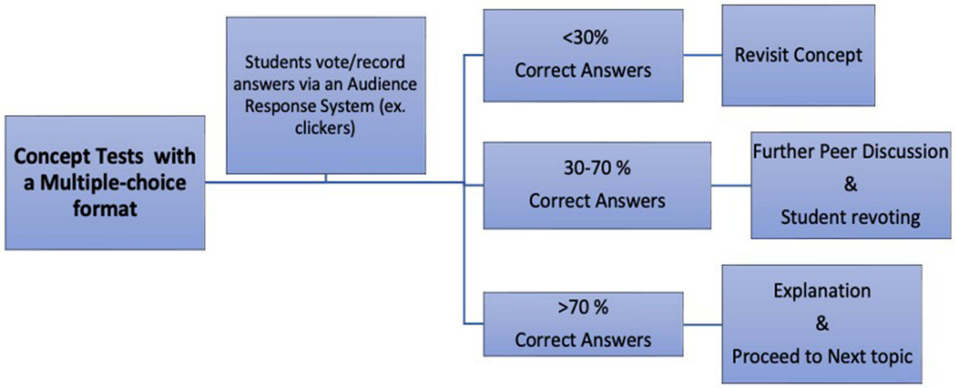

Figure 3 Example of how Concept Test results can be applied in Peer Instruction.

great importance as long as they actively generate and commit to a response.[20] However, it is worth considering the benefits of higher-technology response systems, such as clickers and web-based response systems, in that they offer increased anonymity when students respond compared with using hand signals or flashcards. This encourages all students to participate, even the most introverted and hesitant students, without feeling self-conscious about choosing the wrong answer.[7]

Throughout the literature, there have been numerous instances of ARS usage in STEM classroom settings, with both students and instructors endorsing positive attitudes toward clickers; however, the impact of clickers on student learning has been less transparent and warrants further research.[6,19,21] Some early studies failed to show significant improvements in education when clickers were used merely as a stimulus-response learning method and were not combined with active-learning methods.[22] However, recent studies have shown positive effects on student learning when using clickers with active learning strategies like peer instruction.[6] While some studies comparing the effects of clickers on student learning have been mixed, with some showing no result, other studies have reported a positive impact on student learning.[19] However, it is not easy to compare these studies due to various confounding factors such as class size, course level, instructors, levels of clicker use, and even the effects of outside events.[4,19]

Regardless of the outcome, research has shown that clickers can enhance active learning and improve learning outcomes when used in conjunction with other active learning strategies.[6,19] Over the past few years, ARS, with or without Peer Instruction, has become increasingly popular in medical schools, as evidenced by recent research publications. While various studies have assessed student and educator attitudes towards ARS and its positive impact on student engagement, its direct effect on learning and knowledge retention outcomes has yielded mixed results.[23,24] For instance, in a comparative study involving 294 third-year medical students who were taught clinical microbiology, the effectiveness of clickers were evaluated in six teaching sessions, with three using clickers and three without. After the sessions, students completed an online quiz related to the session and a questionnaire about their attitudes toward the clickers. The results indicated that students had a positive attitude towards clickers. More than half agreed that teaching sessions with clickers were more engaging and agreed that clickers made important concepts more memorable. However, the grades of the online quizzes were slightly lower after sessions where clickers were used, with no significant difference in the grades of students who engaged completely with the process.[23]

Similarly, in a separate study comparing the examination scores in a second-year medical school Pulmonology class when ARS was used, Stoddard and Piquet found that although ARS use may correlate with an improved educational experience, there was no measurable increase in learning.[24] Other studies, however, have reported a distinct improvement in learning outcomes. A study conducted at the University of Valencia (Spain) between 2016 and 2019, aiming to evaluate the impact of clicker quizzes administered at the end of a physiology course on students' academic performance, showed a moderate increase in academic performance due to the intervention. Specifically, although the percentage of failed students remained the same, there was a change in the distribution of scores among the students who passed, with an increase in the number of students receiving a B score (7–8.9/10 points) by approximately 20%, and a corresponding decrease in the number of students obtaining a C score (5–6.9/10 points).[25]

Alexander et al, 2009 aimed to assess the usability and predictive value of an ARS as a knowledge assessment tool in a medical curriculum.[26] The study collected data over three years (2006–2008) from first-year didactic blocks in Genetics/Histology and Anatomy/Radiology, with 42–50 students per class. During each block, students answered multiple-choice questions using the ARS, and students' ARS performances were then recorded and compared with their final examination performances.[26] The study found a statistically significant positive correlation between ARS and final examination scores in all didactic blocks (all $P < 0.0001$). Students and faculty agreed that ARS was easy to use and a reliable tool for real-time feedback that improved their performance and participation.[26]

Similarly, in a study conducted by Nosek et al, an Audience Response System (ARS) was used during a Hematology/Oncology course for 148 2nd-year medical students.[27] Examination scores of participants who used the ARS were compared with those who did not. The mean exam score was 81.9% for non-participants and 85.8% for students who used the ARS at least once. The mean score increased progressively to 94.4% for students who used the system the most.[27] The use of ARS in postgraduate medical education has also gained popularity in the last decade, with overall positive outcomes recorded in research literature in various residency programs. For example, in a plastic surgery

residency program, a qualitative and quantitative study aimed to compare the outcomes of ARS testing with traditional pencil-paper testing, with results indicating that the ARS format led to statistically significantly higher scores (85% with ARS compared with 75% without ARS).[28] However, the disadvantages included start-up clicker costs and lead-time preparation.[28] Similarly, in a two-year study by Hettinger et al, psychiatry residents attended 12 90-min review sessions with Psychiatry Residency In-Training Examination (PRITE) questions and an ARS to provide immediate feedback and a stimulus for discussion.[29] Overall performance improved significantly (p= 0.0068) on PRITE testing when ARS was used compared with pre-ARS scores.[29]

While ARS can be an effective tool for engaging students in undergraduate and postgraduate medical education, its use also has several drawbacks. One of the most significant drawbacks is the time and effort instructors require to prepare the questions and integrate the system into their lecture format.[6] Without proper preparation, ARS can lead to student dissatisfaction and reduced motivation.[6] Another potential drawback is the cost associated with implementing ARS, which may be a deterrent for institutions or students.[30] Technical malfunctions can also be a challenge, as ARS operates on a wireless platform susceptible to software glitches or mechanical issues with the clickers.[30] Additionally, reducing lecture time to allow for questions can be problematic for some instructors who may need to adjust their lecture format to accommodate ARS, potentially leading to omitting important lecture material.[18]

Think-Pair-Share (TPS)

The Think-pair-share (TPS) is a collaborative teaching approach initially introduced by Professor Frank Lyman of the University of Maryland in 1981 and widely incorporated into the Peer Instruction method.[5] In this method, students are first given a question or a problem to think about individually. Then, they are paired with a classmate and asked to discuss their thoughts and compare their answers. Finally, the pairs share their answers and reasoning with the rest of the class. This technique encourages active learning and helps students to understand and retain the material better by engaging with their peers and hearing diverse perspectives.[31] It also allows the educator to assess the understanding of the students and address any misconceptions they may have.[31] Combining individual reflection, small group discussion, and whole-class participation, the Think-Pair-Share technique effectively facilitates learning in a Peer Instruction setting.[5]

A study by Cortright et al, 2005 found that using a variation of Think-Pair-Share in exercise physiology classes along with Peer Instruction improved students' ability to solve new problems.[32] The results showed that students who used PI with TPS had higher rates of answering questions correctly (59%) and answering new problems correctly (47%) compared with students who did not use PI with TPS.[32] Another study assessing the effectiveness of TPS when applied in an associate degree nursing curriculum showed that using TPS improved student engagement and created better outcomes on proficiency assessments. Also, the collaborative nature of the technique encouraged students to prepare more for class and build confidence in their knowledge.[33] A more recent study from the Department of Biochemistry and Molecular Biology at McGovern Medical School in Texas showed that incorporating active learning in a flipped classroom setting, along with the use of TPS, was viewed as an effective teaching method by medical students, with students reporting improvement in their performance on clicker questions, as well as an increase in engagement and participation.[34] These studies have shown that the TPS approach can be easily applied to various areas of study and offers a valuable alternative to traditional, passive lecture-based teaching.

Drawbacks of Peer Instruction

Although Peer Instruction (PI) is a highly effective active learning method, it also has its limitations. One key challenge is that its flexible implementation can lead to variations in classroom norms, which can affect student learning outcomes.[4] Furthermore, PI can be time-consuming, requiring students to engage in discussions that take away from lecture time, making it challenging to implement in large classes or when there is a limited amount of time for a particular topic.[2,4,9] In a survey of instructors who used PI, 10% reported skepticism from colleagues about the benefits of student discussions. In comparison, 9% struggled to cover a sufficient amount of course material in the limited class time available.

In some cases, instructors had to reduce the amount of material covered, which is not always feasible.[9] Another potential challenge is the requirement for instructors to design practical questions and facilitate group discussions, which

requires a certain level of expertise in instructional design and pedagogy, as well as time.[2,4,8,9] According to Fagen's survey, 13% of instructors cited the time and energy required to develop ConcepTests as a barrier to using PI.[9]

Moreover, PI requires students to have a certain level of pre-existing knowledge, as they need to engage in meaningful discussions with their peers.[5,8,9] If students are not appropriately prepared for the peer discussion sessions, it can hinder the quality of the discussions and affect the outcome of PI. Also, during discussion sessions, students are free to discuss often without any group supervision, which might give space for students to discuss topics not necessarily centered around the concepts and topics instructors intend.[4]

At the same time, while PI encourages exposure to new ideas, it can also potentially increase shared misconceptions, especially among students who feel less confident in the classroom.[4] This is why the Audience Response System session is particularly of great importance due to its ability to give real-time feedback. However, the costs of implementing an ARS and the requirement for instructors and students alike to be tech-savvy could also be considered drawbacks.

In addition, PI can be hampered by students' resistance to the method, with 7% of students surveyed by Fagen reporting such resistance.[9] As most students are accustomed to passive learning, some may feel uncomfortable participating in discussions or initially consider the discussions a waste of time. As a result, it can hinder the effectiveness of the Peer Instruction method.

Despite these limitations, PI can still be an invaluable tool for promoting student engagement and active learning in the classroom. While it may not uniformly improve students' course grades, PI has been shown to improve students' reasoning and argumentation skills, which are essential components of learning in any discipline.[4,6] By recognizing and addressing these challenges, instructors can leverage PI's potential to create more engaging and meaningful learning experiences for their students.

Applying Peer Instruction in Medical School Curricula

Although PI has shown significant benefits and positive outcomes in STEM classrooms, only a few research articles have reported its use in medical school courses.[2] The few studies, however, that have examined the use of PI in graduate and postgraduate medical education have yielded consistently positive results, indicating its potential as a powerful tool for enhancing medical education. Studies by Rao and DiCarlo, Trout et al, Versteeg et al, Marina-Gonzalez et al, Passeri and Mazur showed promising results, as summarized in Table 1.[35–39]

Rao et al at Wayne State School of Medicine in Michigan found that using the Peer-Instruction (PI) method in a respiratory section of a medical physiology class improved students' understanding and ability to integrate material.[35] The study consisted of 256 first-year medical students, and the PI technique was used for ten classes. The class was divided into short presentations (12–20 min each) followed by a one-question, multiple-choice quiz on the topics covered in the presentations. Students were given 1 min to think and to record their first answer using a "clicker" and another minute to discuss answers with their classmates. The percentage of correct answers before the discussion was 73.1 ± 11.6%. After the discussion, the percentage of correct answers increased to 99.8 ± 0.24%. This study suggested that PI could be an effective teaching strategy for large classes and increase students' attention and appeal to a more significant number of students.[35]

Trout et al conducted a study using a modified version of Peer Instruction (PI) in a medical school pharmacology course.[36] In this study, they removed the mini-lecture component of the traditional PI method and did not award credit for participation in the session. Instead, lectures were placed online, and readings were assigned. Attendance was not mandatory, and questions and answers were posted online for student review. Examination scores and performance of those who attended with those who did not participate in the PI sessions were compared. The results showed that students who had attended at least one PI session achieved a statistically significant improvement of 8.2% in their examination scores compared with those who had not participated in any PI sessions (82.1% versus 73.9%). The improvement in examination performance was maintained, even as attendance diminished as the sessions progressed. Furthermore, most students who attended the sessions were found not to come from the upper quartile, indicating that the gain in examination performance was not solely attributed to the academic caliber of students attending.[36]

In a study conducted by Versteeg et al in a medical physiology class in the Netherlands, the effectiveness of Peer Instruction (PI) in optimizing comprehension of physiological concepts was rigorously examined.[37] First-year medical

Table 1 Research Studies in the Application of Peer-Instruction in Medical Schools

Research Study	Subject Taught	Medical College/ Region	Study Outcomes
Rao and DiCarlo, 2000[35]	Physiology	Wayne State School of Medicine, USA	The percentage of correct answers increased significantly ($P < 0.05$) after discussion for both recall and intellectual questions.
Trout et al, 2014[36]	Pharmacology	Wright State University, Boonshoft School of Medicine	Students who had attended at least one Peer Instruction (PI) session achieved a highly statistically significant improvement of 8.2% in their examination score compared with those who had not attended any PI sessions (82.1% versus 73.9%).
Versteeg et al, 2018[37]	Physiology	Leiden University Medical Center, Netherlands	The results of the study revealed that both PI and Self-explanation (SE) groups significantly improved their post-test scores ($p < 0.0001$), with PI outperforming SE by 35% compared with 23% ($p = 0.006$).
Marina-Gonzalez et al, 2018[38]	Cardiovascular and respiratory function in health and disease (CRF) module	University College of London (UCL)	• PI improved in-class problem-solving skills • Examination scores revealed that the PI group achieved similar results to those in the previous cohort who attended traditional flipped classroom tutorials.
Marina-Gonzalez et al, 2018[38]	Diseases of the Digestive System (DDS) Module	Universidad de La Laguna (ULL), Tenerife, Spain	Examination scores showed that students achieved a higher number of correct answered questions and averaged scores with the PI module, as compared with the traditional lecture module.
Passeri and Mazuri, 2019[39]	Pre-clinical subjects	A Brazilian Medical School	The PI group demonstrated better performance in both examinations than the control group, with retention of basic science knowledge increasing by 15%.

students (n = 317) were randomly assigned to either PI or Self-Explanation (SE), an active learning technique, and were then given a set of near and far transfer questions to assess their understanding. The study results revealed that both PI and SE groups significantly improved their post-test scores, with PI outperforming SE by 35% compared to 23%. Furthermore, the study found that both methods showed higher transfer scores than the control group, with a tendency for higher near transfer scores for PI, indicating that PI is an effective method for improving comprehension of physiological concepts.[37]

Dr. Marina-Gonzalez and Professors Hernandez-Guerra and Quintero led a joint study across two universities, Universidad de La Laguna in Spain (ULL) and University College of London in England (UCL), to compare the impact of Peer Instruction on academic performance between beginner and advanced undergraduate biomedical/medical students.[38] At UCL, the study used the Cardiovascular and respiratory function in health and disease (CRF) module, which was already delivered using the flipped classroom approach. On the other hand, at ULL, the Diseases of the Digestive System (DDS) module was traditionally offered in a big lecture-based classroom.

The study found that Peer Instruction significantly enhanced the learning experience of all students. The study revealed that Peer Instruction enhances in-class problem-solving skills and produces similar academic benefits to those obtained with small group flipped classroom sessions but with the added benefit of facilitating these results in large classes. Moreover, at ULL, students achieved a higher number of correct answers and averaged scores with the Peer Instruction module compared with the traditional lecture module. Nevertheless, year one students at UCL expressed discomfort in being asked to teach each other rather than have a professor teach them, while year four students at ULL showed higher student satisfaction, implying that more mature students are better prepared for this academic environment.[38]

Passeri and Mazuri (2019) implemented Peer Instruction (PI) in a review session for three medical school pre-clinical subjects in Brazil. They found that students who used PI retained more basic science knowledge on an examination given six months later compared with students who received individual feedback from the instructor.[39] For their study, 226 medical students were invited to participate; 125 were in the control group and received individual feedback from the professor, while 101 students were in the study group and participated in an immediate intervention after the regular examination with a feedback session using the PI method. After the session, the students were given a post-feedback examination (PFE) to identify any changes in their answers compared with the regular examination before feedback. Six months later, a diagnostic examination (DE) was given to identify whether the students retained the concepts covered in the previous examinations.[39] The results showed that the PI group performed better in both examinations than the control group, with retention of basic science knowledge increasing by 15%. The students who received immediate feedback via the PI method had the opportunity to discuss their misconceptions, leading to the highest number of correct answers and demonstrating that when PI is applied in the assessment feedback, it can improve the retention of basic science knowledge.[39]

Applying Peer Instruction in Postgraduate Medical Training

By incorporating peer instruction in postgraduate medical training, healthcare professionals can build upon their prior knowledge and expand their understanding of complex medical concepts. Studies have shown that peer instruction can improve students' critical thinking and problem-solving skills,[31–34] which can lead to better patient outcomes. Additionally, peer instruction can increase motivation and engagement among medical professionals, as it provides them with immediate feedback on their learning progress and allows for self-reflection. However, there is a need for further research to determine the effectiveness of peer instruction in specific medical specialties and to explore the best practices for implementation in postgraduate medical education programs.

One study conducted at Northwestern University Feinberg School of Medicine aimed to showcase the effectiveness of Peer Instruction (PI) and Just-in-Time Teaching (JiTT) as an instructional mode of education for the core curriculum of a residency program. The study was conducted in 2010–2011 with 31 core curriculum sessions taught by 22 faculty members to 31 preliminary and categorical residents. The JiTT/PI strategy involved residents completing web-based study questions before the weekly topic sessions and faculty tailoring the session content based on the residents' learning needs. During the sessions, residents answered multiple-choice questions using clickers and engaged in PI. The study found that 70% of resident respondents felt that JiTT/PI helped in the learning of key points, and 90% of faculty respondents reported positive perceptions of the strategy. Resident engagement time for JiTT/PI sessions was higher compared with prior lecture-based sessions, and more review session MCQ responses were correct for residents who attended corresponding JiTT/PI sessions. The study concluded that JiTT/PI is an effective approach for meaningful and active learning in core curriculum sessions, increasing learner participation, retention, and learner-centered time.[40]

With limited clinical time for residents and high clinical demands on faculty, it is essential to use education methods that maximize engagement and learning during residency didactics. The PI method offers an effective solution, allowing residents to participate in active and meaningful learning while maximizing the value of face-to-face time with faculty.

Applying Peer Instruction in Interprofessional Medical Education

Interprofessional Education (IPE) in medicine refers to educational programs and initiatives that bring together healthcare professionals from different disciplines to work collaboratively, share knowledge, and enhance patient care.[41] IPE emphasizes the importance of interdisciplinary collaboration, understanding the role and responsibilities of each profession, and developing teamwork and communication skills.[42] By working together, healthcare professionals can share their unique perspectives and learn from one another, which can improve patient outcomes and increase the overall quality of healthcare delivery.[42] IPE programs can take various forms, such as joint classes, simulation exercises, and clinical rotations, and are designed to prepare healthcare professionals to work effectively as a team in the complex and rapidly evolving healthcare landscape.[41,42] The integration of Interprofessional Education (IPE) into healthcare curricula globally has led many medical educators to focus on finding and implementing effective teaching methods to achieve the core competencies of IPE.[43]

Bucheit et al argued that the Peer Instruction Method could be an ideal fit for Interprofessional Education (IPE). The research explored the application of Peer Instruction method in a family residency program to provide interprofessional education (IPE) during didactic sessions. Pharmacy and medical students were recruited for a session that was based on learners' answers to 80 questions submitted two weeks previously. The session was facilitated by one family medicine resident, one physician, and one pharmacy faculty member, who tried to distribute the learners evenly into interdisciplinary teams. During the session, the learners answered questions using "clickers" before and after group discussions and had the opportunity to express their viewpoints. The session resulted in changes in learner perceptions towards IPE, as shown by surveys before and after the session. These changes reflected the learning community as a whole rather than being profession-specific. The article concluded that the Peer Instruction Method could be effectively used in didactic sessions for family medicine residency programs, provided the scheduling and choice of topics are carefully considered.[44]

Despite the growing recognition of the importance of Interprofessional Education (IPE) in modern medical education, there is still a need for further research to understand fully the potential benefits and limitations of Peer Instruction method for IPE. While the above study demonstrated positive results from incorporating Peer Instruction into IPE programs, there is still much to be learned about the best ways to effectively integrate this method into a diverse range of IPE curricula. This includes understanding the role that Peer Instruction can play in facilitating interdisciplinary collaboration and communication and promoting the development of core IPE competencies such as teamwork and patient-centered care. By exploring the benefits and challenges of Peer Instruction in IPE, medical educators can make informed decisions about the most effective educational methods to use and work towards ensuring that future healthcare professionals are equipped with the interprofessional skills they need to provide high-quality patient care.

Limitations in Peer Instruction Research in Medical School Settings

While Peer Instruction has become increasingly popular among educators across various disciplines, its application in medical education has not been extensively researched.[2,6,8,9] In 2015, Vickrey et al, in a literature review, estimated that only 4% of research articles referred to the application of PI in a medical classroom.[2] Similarly, the authors recent PubMed search for research articles on Peer Instruction application in medical schools with year parameters from 2015–2023 generated only a few results, with many results referring to Peer-assisted learning (PAL) instead of Peer Instruction (PI).

It is evident that despite its well-established framework and effectiveness in promoting student engagement and learning outcomes, there is a lack of formal recognition and acknowledgment of PI as a distinct instructional method. As a result, many instructors may implement different combinations of the PI components without necessarily referring to it by its official name. This ambiguity makes finding and reviewing research articles on PI difficult, with some arguing that any active learning method that uses an ARS and Concept Tests could be considered a form of PI. While this argument has some validity, it is essential to note that PI is more than just a combination of these two components. PI is a pedagogical approach that involves a specific set of principles and practices, including peer discussion, promoting student autonomy, and aligning assessment with learning objectives. Therefore, while there may be an overlap between PI and other active learning methods, it is important to recognize the unique features and benefits of PI as a distinct pedagogical approach.[2,6,8,9]

Another reason for the scarcity of research articles on PI in medical education, in part, could be due to the traditional emphasis on individual learning in medical education, which often prioritizes direct instruction over collaborative, multistep education methods. As a result, medical educators may be more inclined to rely on traditional teaching techniques such as lectures and case studies, which may not lend themselves as readily to the PI format. Moreover, the highly structured nature of medical education, with its focus on specific learning outcomes and competencies, can create challenges for the implementation and research of PI. For example, the emphasis on standardized testing and certification requirements in medical education may lead instructors to prioritize the coverage of a large volume of material, leaving less time for the extended periods of discussion and reflection central to PI. Despite these limitations, the potential benefits to student learning and engagement suggest that Peer Instruction is a pedagogical approach that warrants further attention and research.

Conclusion

The application of the Peer Instruction method in medical schools has shown promising results in enhancing students' engagement and learning outcomes. The technique encourages students to participate in their learning process actively, promotes critical thinking, and fosters collaborative learning. The research findings indicate that the peer instruction method positively impacts students' academic performance, confidence, and satisfaction with the learning experience. The peer instruction method has the potential to transform traditional teaching approaches and improve the quality of medical education. Therefore, medical schools should consider incorporating the peer instruction method in their educational strategies to enhance their students' learning experience. Finally, further research is needed to explore the long-term effects of the technique and its effectiveness in different medical disciplines.

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