Effect of Language and Cultural Factors on the Implementation of Peer Instruction in Physics

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Implementing Peer Instruction (PI) from one country to another is an under-examined process. PI was developed in the United States. Although research shows that implementing PI contributes to positive learning gains and attitudes, little is known about the generalizability of its effectiveness in other countries. One cannot assume that such an instructional strategy developed elsewhere can be easily implemented into a unique context in terms of language and culture. When the students' first language is not the language of instruction, there may be unique challenges to effective peer discussion in physics, and when the culture from high school has been to take instruction from the teacher, discussion in class may be hard to establish.

This research involved analysis of pre-FCI assessments conducted in Arabic and English among students in introductory Physics courses, highlighting performance differences based on language, major, and gender. Moreover, traditional teaching methods were compared with PI during online learning due to COVID-19, utilizing pre- and post-Half FCI assessments and CLASS surveys. In addition, interviews were conducted with teachers and students to explore their perspectives on PI and related practices, emphasizing language use and cultural dynamics in classroom interactions.

The findings revealed overall low FCI scores among students, with engineering students slightly outperforming science students. Language influenced comprehension differently across individual FCI questions, and dominant misconceptions persisted regardless of language. While both teaching methods resulted in slight improvements in understanding and attitudes, traditional instruction yielded marginally better learning gains and positive shifts in attitudes. Nevertheless, no significant differences in normalized learning gains were found between teaching methods. Interviews indicated that teachers recognized the challenges posed by language barriers, while students preferred using Arabic for discussions. Cultural norms affecting classroom dynamics were also identified, with male students dominating discussions. Both teachers and students acknowledged the benefits and challenges of PI, emphasizing the need for strategies that bridge their divergent perspectives.

This study contributes to the understanding of how language and cultural factors impact the implementation of instructional strategies like PI in physics education. Highlighting the complexities of language use and cultural norms in classroom interactions provides valuable insights for educators seeking to enhance student

engagement and comprehension in diverse educational settings. The findings highlight the importance of addressing language and culture-specific challenges to improve the effectiveness of peer instruction across different contexts.

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Chapter 1
Introduction

1.1 Active Learning and Peer Instruction

Active learning is a student-centred instructional method, which requires students to engage in meaningful learning activities that allow them to think deeply about what they are doing. Research found that students engaged in active learning retain more information compared to those taught in the traditional lecture format (Hake, 1998). Moreover, it has been found that active learning methods are effective for developing problem-solving skills, students' thinking, and motivation.

One such active learning method successfully used in physics is Peer Instruction (PI) (Crouch, 1998). PI is a student-centered learning method that lets students discuss physics concepts with their peers during class time. It is based on the constructivist learning theory and social constructivist approach to learning, in which social interaction plays a crucial role in the construction of knowledge, and where discussion and collaboration between peers have a positive impact on learning (Bada, 2015).

PI is often implemented as a combined teaching model, with other instructional strategies such as Just in Time Teaching strategy, where students are expected to read the topic to be addressed and complete a corresponding assessment before each class (Mazur & Watkins, 2010). Moreover, students can solve problems with Cooperative Group Problem-Solving Activities (Patricia Heller & Hollabaugh, 1992). During PI, the instructor begins the class with a short presentation focused on a central point, which is followed by a related conceptual question in the form of multiple-choice questions which probe students' understanding of the ideas presented. These conceptual questions are designed to uncover students' misconceptions in the material presented. Students first answer a question on their own and provide their answer anonymously through an e-polling tool. Depending on the percentage of students that answer correctly, students are then asked to discuss their answers with their peers and then re-submit their answers. These discussions allow students to uncover their misunderstandings in the material. Students' initial and secondary responses to the related questions give the instructor an idea about the collective class's understanding of concepts being covered. Therefore, lecture meetings consist of sequences of posing questions, answering questions, and discussing the questions in small groups of students (Crouch & Mazur, 2001).

PI was first developed by Eric Mazur at Harvard University in 1991 (Mazur, 1997). Since then, it was implemented in many universities around the world (Fagen et al., 2002; Lasry & College, 2006; Pilzer, 2001; Zingaro & Porter, 2014).

1.2 Peer Instruction and Learning Theories

Peer instruction is an instructional strategy that utilizes the social dynamics of learning to enhance student engagement, foster conceptual understanding, and improve knowledge retention. This method of instruction is grounded in several learning theories, mainly constructivism, social learning theory, and cognitive load theory. Each of these theories contributes to a comprehensive understanding of how peer instruction can be effectively implemented in educational settings.

1.2.1 Constructivism

Peer instruction is fundamentally rooted in the learning theory of Constructivism that stresses learners' engagement in constructing their understanding and knowledge by reflecting on experiences. This theory is primarily linked to the work of Jean Piaget and Lev Vygotsky, who highlighted the significance of interaction and collaborative learning (Piaget, 1954; Vygotsky, 1978).

Constructivism emphasizes that learning is not passively taking in information but rather involves an active engagement where learners draw upon their existing knowledge to construct new understanding and insights, through interaction and discussion with peers. This is particularly relevant in peer instruction (Gok & Gok, 2017).

In a peer instruction setting where students teach each other informally, they discuss ideas and work together to solve problems leading to the creation of knowledge in a meaningful way (Crouch & Mazur, 2001).

1.2.2 Social Learning Theory

Social learning theory, developed by Albert Bandura, further emphasizes the significance of observational learning and the social context of learning (Bandura, 1977). According to this theory, individuals acquire knowledge and behaviors by observing others and engaging in interactions that are essential in shaping their behavior and understanding of the world around them. In peer instruction settings, students not only gain knowledge from their peers, but they also mimic their behaviors and cognitive practices. The teamwork aspect of this method

motivates students to observe problem solving strategies and logical thinking methods that enhance their educational experiences (Gokhale, 2000).

Furthermore, social learning theory emphasizes the role of motivation and reinforcement in the process of learning. Peer teaching fosters an encouraging learning setting enabling students to feel at ease with asking questions and giving feedback (Dillenbourg, 2007). This feeling of community improves motivation and engagement and both are critical aspects for effective learning.

1.2.3 Cognitive Load Theory

John Sweller's cognitive load theory provides insights into the processes of learning and instruction (Sweller, 1988). This theory proposes that individuals have a limited capacity for processing information simultaneously, and that instructional techniques should be optimized to work within these constraints to enhance learning outcomes effectively. Therefore, peers who are working together can help manage load by sharing the effort needed to understand difficult concepts. When students collaborate in studying or problem-solving tasks, they lighten each other’s cognitive load, which makes it easier for them to grasp and remember the information presented.

Furthermore, peer instruction can help reduce the burden of effort by allowing for active involvement and communication. When students articulate ideas to each other they are less prone to feeling overwhelmed, compared to when they learn in lecture settings (Van Merriënboer & Sweller, 2005). The active involvement demanded in peer teaching encourages an intrinsic cognitive load that is crucial, for thorough comprehension and lasting memory retention.

Overall, peer instruction stands out as a teaching method that is deeply rooted in constructivist learning theory, social learning theory, and cognitive load theory. By encouraging participation and teamwork while also fostering cognitive thinking skills in students; peer instruction elevates their grasp of concepts and helps them in knowledge retention. As researchers in education delve into creating engaging student focused learning atmospheres; the theoretical foundations of peer instruction offer a groundwork for understanding its effectiveness.

1.3 Hofstede's Cultural Dimensions Theory

The study of cultural factors, particularly as formulated by Geert Hofstede, has become a foundation in understanding the interplay between culture and various societal practices, including education. The dimensions outlined in Hofstede’s

theory shed light on how cultural values shape behavior in different cultural settings such as educational practices (Hofstede, 1986). The following discussion will delve into these dimensions and their connection, to teaching approaches, whether traditional teaching or peer instruction.

Power Distance

In societies with high Power Distance, like Asian countries mentioned by Hofstede, a hierarchical structure is highly emphasized in educational settings, where teachers are respected as figures of authority. Traditional teaching approaches involving lectures and memorization are common to uphold the teacher's authority and maintain students in passive roles. In contrast, low Power Distance cultures like Scandinavian countries promote open relationships in classrooms where peer instruction and collaborative learning are frequently seen (Hofstede, 2001).

Individualism vs Collectivism

The comparison between Individualism and Collectivism focuses on how people priorities personal goals versus group objectives in different cultures. In countries such as the United States that value success and self-reliance, according to Hofstede's research, traditional teaching methods that encourage independent learning are preferred. On the other hand, in collectivist societies, like Asian and African countries, where group effort and collaboration are emphasized based on Hofstede’s findings, peer instruction is seen as a more effective way of teaching (Geert & Hofstede, 2004). A research study found that students who value collectivism tend to excel in settings that promote collaboration and mutual knowledge sharing (Smith & Bond, 1999).

Masculinity vs. Femininity

The comparison between Masculinity and Femininity delves into how emotional roles are divided among genders in cultures; Masculine societies tend to emphasise competitiveness and success while favoring conventional teaching techniques that highlight personal performance and achievements (Hofstede, 1986). On the other hand, Feminine cultures place a value on interpersonal connections and care, which often results in a more positive stance towards peer instruction and collaborative learning strategies, as observed in Hofstede (Geert & Hofstede, 2004).

Uncertainty Avoidance

High Uncertainty Avoidance relates to how comfortable people are feeling, with unclear situations and how much they try to avoid uncertainty in these situations. In cultures like Greece and Japan, where this is prevalent, the preference is for

teaching approaches that are well-defined and predictable. Such cultures may not readily embrace newer teaching methods like peer instruction that bring in an element of unpredictability into learning (Geert & Hofstede, 2004). In contrast, countries with low Uncertainty Avoidance, like the United States and Sweden, tend to embrace teaching approaches like peer instruction due to their familiarity with handling uncertainty in different environments (Hofstede, 2001).

Long-Term vs. Short-Term Orientation

The comparison between Long-Term and Short-Term Orientation reveals how different cultures prioritise future rewards compared to immediate gratification. The aspect of long-term orientation is evident in countries like China and Japan where there is a focus on persistence and education as essential for reaching long-term objectives (Hofstede, 1986). Traditional teaching that highlights discipline and hard work aligns well with these values. In contrast, societies with a focus on short-term goals like the United States tend to prefer teaching approaches that are interactive and yield immediate feedback, for instant satisfaction (Geert & Hofstede, 2004).

Indulgence vs. Restraint

The dimension of Indulgence versus Restraint evaluates how much a society permits the gratification of basic human desires. In Indulgent cultures, such as those in Latin America, often prefer a more relaxed approach to education, favouring interactive and engaging teaching methods like peer instruction (Hofstede, 1986). On the other hand, Restrained cultures may follow stricter educational approaches that emphasise discipline and control, leading to a prevalence of traditional teaching methods (Geert & Hofstede, 2004).

1.3.1 Omani Culture within Hofstede's Dimensions

In Oman as a country in the Arab region, there is a unique culture that can be interpreted through the lens of Hofstede’s cultural dimensions. Studies have shown that Oman tends to score relatively high in Power Distance according to Hofstede's insights (Tlili et al., 2021).This indicates a culture characterized by a deep respect for authority and hierarchical relationships. The emphasis on Power Distance in Oman may impact instructional approaches by favoring traditional teaching methods where teachers are seen as the main providers of knowledge.

In terms of Individualism vs. Collectivism, Oman's culture leans more towards collectivism by prioritizing family and community connections (Tlili et al., 2021). This cultural preference could support peer teaching as a method that encourages students to work together collaboratively in learning environments.

Therefore, implementing peer teaching within established programs in Oman could significantly improve student involvement and academic achievements.

Oman's score on Uncertainty Avoidance is moderate, suggesting a balanced approach to structure and flexibility in educational settings. This trait could facilitate the integration of new teaching techniques alongside the conventional approaches (Tlili et al., 2021). Additionally, Oman's Long-Term Orientation indicates a cultural emphasis on education as a means of preparing for the future, which suggests an openness to teaching methods that encourage critical thinking and problem-solving skills (Obeidat et al., 2012).

1.4 Implementation of Active Learning at Sultan Qaboos University (SQU)

Over recent years at Sultan Qaboos University (SQU), there has been a noticeable decline in the students' performance in introductory physics courses accompanied by a drop in the number of students who choose physics as their major of study. It was also noted that the students were not able to transfer knowledge from one physics course to the next. i.e., students forget all information after they complete the course. To counter this, the Physics Department decided to move out of instructor-centred approach to student-centred learning approach. Therefore, active learning became a part of the Physics Department strategic plan and was also recommended by the external review team, which visited the Department in 2016. The team consisted of experts from Cambridge University (UK), Penn State University (US) and Texas at Arlington University (US). Currently, active learning is also required by the University strategic plan, and it is the first project in the 2021-2025 strategy. Among different active learning methods, two methods were suggested to be implemented, namely: Peer Instruction and Cooperative Groups Problem Solving (Patricia Heller & Hollabaugh, 1992).

1.4.1 Peer Instruction Implementation at SQU

Some faculty members in the Physics Department at SQU are interested in physics education and have a wide knowledge about research based instructional strategies (RBIS) including active learning. These faculty members took the effort of introducing active learning to other members of the department through talks and workshops. There was a strong resistance from faculty to this new approach of teaching. There were doubts that this transition to the new

approach needs time and effort and does not suit our students, who prefer to stay passive and refuse to participate during lectures. Despite this resistance, three instructors, including the head of the department, were able to introduce active learning to physics 1 for science course in Spring 2018. They planned the course together following the guidelines in the PI user manual by Eric Mazur (Mazur, 1997) and had weekly meetings to reflect on their experiences and practices with the new type of instruction. The design of the first PI course took the following form:

A. **Before the Lecture:** Students are expected to read an assigned section from a chapter and take an online reading quiz.

B. **During Lecture:** Students are expected to participate in PI questions using the Google Classroom platform on mobile phones. This allows the instructors to record the students' answers on their computers and display them in real time as a histogram. There are two 80-minute lecture sessions per week.

C. **After Lecture:** Students are asked to solve an online homework assignment on a weekly basis.

D. Students attend a one-hour tutorial session every week and work in a team of three to solve a context-rich problem.

E. In some weeks, students must attend an experimental session just after the tutorial session to do experiments related to materials taught in lecture.

PI method was introduced to lecture sessions, which take place in a large lecture hall setting that can occupy up to 120 students. Along with PI, the cooperative group problem-solving method was introduced to tutorial sessions, which take place in large laboratories, which can occupy up to 60 students. The implementation of this later method is described in section 1.4.2. Another instructor was assigned to coordinate the tutorial sessions under the supervision of the three instructors. The first implementation process required a huge amount of time and effort. Instructors of tutorial sessions were carefully selected. The criteria at this early stage of implementation were that they must have permanent appointments, they must not be graduate students, and they preferably be at a relatively young age to adapt faster to the new method. Later, the department continued to implement active learning in other introductory physics courses among which are the two courses under study, which are listed in **Table 1-1**. However, due to the circumstances of COVID-19 and online learning, Physics 1 for Engineering reverted to traditional teaching.

The second implementation of PI to other courses differed from the first one because more instructors were needed, and these instructors had no or little knowledge about PI and physics education research. Therefore, the three expert instructors were distributed to different courses and each one of them took the responsibility of training the new instructors to active learning.

Course	**Topics**	**Colleges**	**Teaching Method**	**First Implementation of PI**
PHYS I for Science	Mechanics	Science, Agriculture, Nursing, Education	PI	SPRING 2108
PHYS I for Engineering	Mechanics	Engineering	PI	FALL 2019

Table 1-1 Introductory physics courses under study and PI implementation (Note: Physics 1 for Engineering reverted back to traditional teaching during the period of data collection of this research).

1.4.2 Cooperative Groups Problem-Solving Implementation at SQU

The second primary form of active learning in introductory physics courses at SQU is cooperative group problem-solving. This method was implemented along with the PI and is primarily used in tutorial sessions. It was developed at the University of Minnesota and has since spread to become one of the leading and most effective active learning methods used in the U.S. (Patricia Heller et al., 1992; Patricia Heller & Hollabaugh, 1992). This approach conducts tutorials in small groups of 3 or 4 students. These groups are pre-determined by the tutorial coordinator. A role is assigned to each group member. These roles are the manager, recorder and questioner. The groups are shuffled every three weeks, and the assigned roles are shuffled weekly. Each tutorial consists of one context-rich problem (CRP), and the groups are asked to solve it following a specific problem-solving strategy. A guiding answer sheet is distributed to ensure that the students follow this strategy, and the students are asked to complete it step by step. An example of a context-rich problem and the answer sheet is presented in Appendix A.

The department dedicates a significant effort to preparing context-rich problems related to the Omani context and holds special “brainstorming” sessions for staff

every semester to prepare them. All academic staff in the physics department must submit at least one context-rich problem each semester. There are different ways to prepare for such problems. One way is to choose a normal textbook problem and put it in a context, which is related to everyday life. Another way is to choose a rich context problem from the American developers and adapt it to the Omani context (Pat Heller & Heller, 2018). A third way, and the most innovative and time-consuming is to write the context-rich problem from scratch.

1.5 School Education System in Oman

This report would not be complete without highlighting key features of education in Oman. This section provides an overview of education systems in schools and SQU.

The School Education System in Oman consists of pre-school, public and private school education.

1.5.1 Pre-School Education

The pre-school education is offered by the private sector for children from three to six years old. However, the Ministry of Education (MoE) is responsible for the technical supervision of all schools and centres that provide pre-school education programs. Curriculums vary from fully Arabic curriculum to fully English curriculum.

1.5.2 Public School Education

Public school education is free of charge and comprises the following:

Basic Education:

Basic education is divided into two cycles:

- Cycle 1 (Grades 1 – 4): Schools contain students from about six to ten years old of both sexes. The teachers in these schools are all females. English is taught as a main subject by non-native English teachers. All courses including math and science are taught in Arabic.

- Cycle 2 (Grades 5 – 10): Schools contain students from about 11 to 16 years old. At this level, male and female students are taught in separate schools. According to that, the staff can be either made up of males or females. English is taught as a main subject by non-native English teachers. All courses, including math and science, are taught in Arabic (educouncil, 2020).

Post-Basic Education (Grades 11-12)

Schools contain students from about 17 to 18 years old. This level represents the education in grades 11 and 12 after completing the second cycle of basic education. Male and female students are taught in separate schools. Accordingly, male students are taught by male teachers, and female students are taught by female instructors. English is taught as a main subject by non-native English teachers. Physics, Chemistry, Biology and Mathematics are taught in Arabic. The physics of grade 11 covers mainly topics of Newtonian mechanics, and the physics of grade 12 covers mainly topics of electricity and magnetism.

Post-basic education is a bridge between the basic education stage and higher education, so it is worth mentioning here that the issue of teaching methods is given particular attention by the MoE. Teachers are advised to avoid basing their teaching and assessment on rote learning and memorization. Workshops and other means of training were held to train teachers to apply learning through experience away from a Teacher-Centered approach. The MoE fostered the application of the Student-Centered approach, where students are the center of education, encouraging them to investigate, find answers to questions themselves, transmitting first-hand learning, working in cooperative groups, and inviting students to express their views and engage in participatory learning. Issan & Gomaa, 2010 stated that if we look closely at how successful teachers and administrators have been in introducing these recommended practices. One can say that teachers are not well prepared and trained to implement the new teaching approaches.

Furthermore, the school buildings and facilities such as labs, workshops, are not well developed to cope with the new demand of implementation (Issan & Gomaa, 2010).

1.5.3 Private School Education:

The Ministry of Education provides general supervision of private schools. That is examining and approving the educational programs and curricula adopted in these schools. There are several types of schools offering private education:

Monolingual Schools:

These schools have both male and female students. Students are taught by male or female teachers at all levels of education. Like public schools, they offer English as a main subject. All courses, including math and science, are taught in Arabic.

Bilingual Schools:

These schools have both male and female students. Students are taught by male or female teachers at all levels of education. Science and mathematics subjects are taught in English. A higher-level English subject is also taught compared to public schools, but mostly by non-native English teachers.

International schools:

These schools contain both male and female students. Students are taught by male or female teachers in all levels of education. These schools offer educational programs and curricula accredited by international education systems/bodies, where English is the main language of study. English is taught by native English teachers. This is one of the reasons that these schools are so expensive, and only an exceedingly small population can afford this type of education for their children.

After grade 12 and based on their grades, students can pursue higher education. Higher education is the responsibility of the Ministry of Higher Education, and it includes Sultan Qaboos University (SQU), the Colleges of Education, Technical Colleges and Institutes and private universities and colleges.

1.6 SQU Education System

Sultan Qaboos University was established in 1986 as the first government university in Oman. It contains eight colleges: Medicine and Health Sciences, Engineering, Agriculture and Marine Sciences, Science, Education, Arts and Social Sciences, Economics and Political Sciences, and Nursing. The university

follows a semester system, which divides the academic year into two semesters: fall and spring. Each semester is 15 weeks of teaching plus 2 weeks of final exams with a winter break in between the fall and spring semesters and a summer break after the spring semester.

Sultan Qaboos University admits students who successfully completed their grade 12. However, entry is highly competitive and based on examination scores because the intake capacity of the University is quite limited.

Upon admission, SQU offers a mandatory Foundation Program for all new students. The program is designed to prepare new students to achieve the required learning outcomes following the academic standards of the Omani Authority for Academic Accreditation (OAAA). This program focuses on preparing students in English language, Mathematics, Information Technology and Study Skills regardless of the degree they go on to. These courses are mandatory for all university students depending on their results in the placement tests.

During the orientation period before any teaching commences, Placement and Exit tests are administered to all students who are admitted to the university to determine each student’s proficiency level in English, Math and IT. Based on the results of the tests, students are allocated to courses and groups of equal ability.

Examples of courses that are offered in the Foundation Program are:

English for Sciences I: This is a semester-long course which students enter at a pre-intermediate level of English proficiency. The course encompasses all English language skills as well as elementary academic and research skills (e.g., taking lecture notes, using the American Psychological Association (APA) reference style, and paraphrasing sources). In addition to intensive practice in the four main language skills, students engage in extensive reading and general and academic vocabulary acquisition activities.

English for Sciences II: a semester-long Foundation Program English Language (FPEL) course which covers the general basic skills of reading, writing, listening, and speaking. This course also continues to consolidate study skills which are necessary for college work. The second half of the course develops language-usage specific to students' specializations. Students are assessed through a combination of continuous assessment and formal examinations at mid- and end of semester.

English for Sciences III: This is a semester-long Foundation Program English language for sciences course which covers the skills of reading, writing, listening, and speaking in the context of students’ specializations. This course also continues to consolidate study skills necessary for college work and equips

students with skills crucial for drafting a 500-word report. Students are assessed through continuous assessment and formal examinations at the mid- and end of the semester.

After finishing the foundation program, students can proceed to study courses related to their main program of study (SQU, 2020).

1.7 Purpose of this Study

The researcher had been part of the team that coordinated the tutorials part of Physics I for science. Through continuous observations of students while they are working in the tutorials and through discussions with instructors of lectures and tutorials, she had some concerns:

1. Students spend too much time translating context-rich problems from English to Arabic to understand them.

2. Students discuss the problems with their peers and Arabic instructors in Arabic.

3. Students come to the tutorial still not mastering basic physics terminology, such as inclined plane.

4. Even though they already encountered the physics concepts in the PI sessions, they still cannot relate them to the context-rich problems. They just try to see the variables and look for equations to plug these variables in.

5. Some instructors insist that they should engage in traditional problem-solving, where the instructor solves the problems in front of the students, but other instructors claim that this detracts from the purpose of active learning.

In general, students in our introductory physics courses seem to be experiencing some issues. All the students who joined these courses have previously been taught physics in Arabic. On entering the university, they face a change, with physics and science courses, in general, taught in English. Moreover, these students are accustomed to teacher-centered learning in schools, and they appear to have issues when adapting to student-centered learning in our introductory physics courses.

These observations, along with many others, led the researcher to propose an investigation into further possible factors of culture and language that affect students' learning, as per the PI. It is worth mentioning that the researcher was not involved in any teaching activity at SQU during this study. Of course, the researcher is aware of the difficulties in studying all aspects of active learning, which may be influenced by cultural and linguistic factors. Thus, out of necessity, the focus of this PhD study is on the effects of culture and language on students’

understanding, students' attitudes, student-student interactions, student-teacher interactions and instructors' and students' perspectives.

This study intends to ease the implementation of active learning for other courses in the physics department and hopefully other departments at SQU, to pave the road toward active learning for other countries with similar education systems, culture and language, and most importantly to fill a gap in the current physics education research because the researcher is not aware of similar research that study the effect of language and culture on the implementation of peer instruction.

1.8 Research Questions

For all the above reasons, this study aims to answer the following research questions:

Research Question 1: How do the language and cultural factors affect students' conceptual understanding of physics?

Research Question 2: How does the teaching method affect students' learning gain and attitude toward physics?

Research Question 3: How do the language and cultural factors affect student-student and student-teacher interactions?

Research Question 4: What are the students' and teachers' perspectives on peer instruction?

This thesis will provide an overview of the literature related to the implementation of active learning. Chapter 2 will examine the roles of language and culture in education. In Chapter 3, a description of the research methodology used to address the research questions will be provided. In Chapter 4, the prevalent misconceptions held by students prior to any university physics instruction, in both Arabic and English, will be identified and described. In Chapter 5, the impact of teaching methods (traditional teaching versus peer instruction) on student conceptual understanding and attitudes will be examined. In Chapter 6, the language and cultural factors affecting student-student and student-teacher interactions, as well as the perspectives of students and teachers on peer instruction, will be investigated. In Chapter 7, the conclusion and suggestions for future work will be presented.

Chapter 2
Literature Review

The pedagogical landscape of higher education, particularly in the sciences, has increasingly recognised the significance of instructional strategies that promote active learning and student engagement. Peer instruction, a method developed by Eric Mazur in the early 1990s, has gained traction for its potential to enhance conceptual understanding and facilitate collaborative learning (Mazur, 1997).

Since PI was introduced in 1991, there has been a considerable amount of research conducted to investigate various aspects related to this active learning method (Gok & Gok, 2017; Vickrey et al., 2015). There are many studies focused on the effectiveness of peer instruction on high school, college, and university students' performance (Lasry et al., 2008; Rao & DiCarlo, 2000), conceptual learning, problem solving, critical thinking, perception (Simon et al., 2013), attitudes (Slaughter et al., 2011; P. Zhang et al., 2017), motivation, confidence (Gok, 2013), beliefs, etc., in comparison with traditional teaching methods. Moreover, other studies examined the effectiveness of peer instruction on gender factor (Lorenzo et al., 2006). Several studies reported the impact of instructors' teaching experience and students' academic background on PI (Finelli et al., 2018; Lasry et al., 2008).

It is worth mentioning that most of these studies have been conducted in the US, where PI initially originated. However, this active learning method is now used in many countries around the world with different cultural backgrounds. To fill this gap in the literature, a meta-analysis study was conducted by Balta et al., 2017 to examine the effect of PI in different countries and found an interesting result, which is that the learning gain was found most significant in Finland, Thailand, Brazil, Argentina, Turkey, and Denmark, while France and the USA had the least learning gain. Despite the limited number of studies included in this meta-analysis, these preliminary findings opened new directions for future PI research about the universality of this type of active learning method that, to our knowledge, has not been studied before. Therefore, we decided to explore further the factors of language and culture in implementing PI.

This literature review examines the interplay between language and cultural factors in implementing peer instruction in Physics, particularly within the context of Sultan Qaboos University. The review is structured around the research questions posed in this study, which focus on the effects of these factors on students' conceptual understanding, interactions within peer instruction, and the perceptions of both students and teachers regarding this instructional approach.

2.1 Factors Affecting Implementation of Peer Instruction

Behind the success and effectiveness of PI, lie many challenges and barriers in the implementation of this active learning method (Fagen et al., 2002). Because of these challenges, many PI users quit using it after some time (Henderson et al., 2012). These barriers can be classified into different contexts as shown in Figure 2-1.

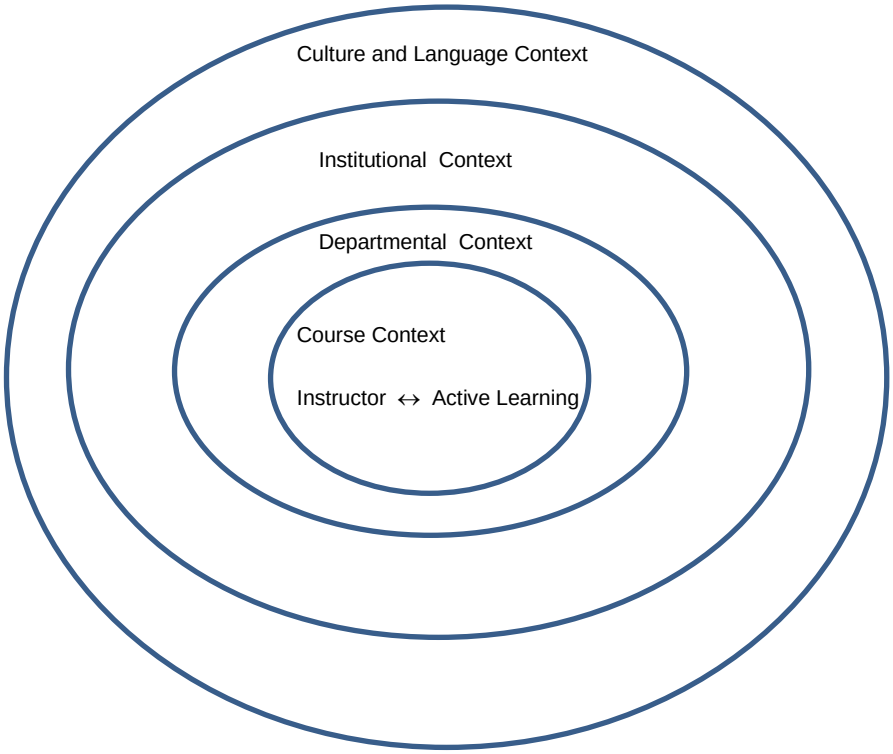


Figure 2-1 Frames of context that affect the implementation of active learning. Adapted from (Finkelstein, 2005; Turpen et al., 2016)**.**

Studies show that there are individual constraints to implementing active learning. These constraints have to do with the instructors themselves, such as security of employment, research activity, and prior exposure (Henderson & Dancy, 2007).

Other studies explored more barriers regarding course context, such as class size, classroom setup, and students' resistance (Dancy & Henderson, 2005).

Other challenges rise from departmental and institutional contexts within which active learning is applied such as expectations of content coverage, how faculty talk about and collaborate in teaching, how faculty respond to experimenting with innovative approaches to teaching, providing resources for instructional

innovation, and material constraints such as technology availability, classroom space layout, etc.(Turpen et al., 2016).

To the researcher's knowledge, there are no studies that explored the effect of the context of culture and language on the implementation of Peer Instruction. In the following sections, we will highlight literature related to culture, language and teaching methods.

2.2 Language and Cultural Factors in Education

Language plays a significant role in education by impacting communication and cognitive functions as well as shaping cultural identity in diverse educational environments. Moreover, language can serve as a useful tool for learning and a barrier at the same time, especially when the language of instruction is not the native language of students (Cummins, 1992; Keefer & Haj-Broussard, 2020). In the context of physics education, where complicated terminology and abstract concepts are prevalent, the language of instruction can significantly impact students' comprehension and engagement (Krabbe et al., 2021).The language challenges faced by non-native speakers can make it difficult to grasp scientific concepts, leading to misconceptions and a lack of confidence in their abilities (College, 2024).

Cultural factors further complicate the educational settings. Culture shapes students' approaches to learning, their interactions with peers and instructors, and their overall engagement with the subject matter (Hofstede, 2001). In collectivist cultures, for example, students may prioritise group work and collaboration over individual achievements, which can influence their responses to peer instruction (Triandis, 1995). Understanding these cultural factors is critical for ensuring a successful implementation of peer instruction, as it may require some adaptations to fit the cultural context of the learners (Balta et al., 2017).

2.3 Language, Culture and Conceptual Understanding

Research has constantly shown that students hold many misconceptions about physics, which are often deeply rooted and resistant to change (McDermott, 2004). These misconceptions can arise from everyday experiences, informal learning, or even the language used in teaching. For example, students may mix the concepts of force and motion, thinking that an object in motion needs a continuous application of force (Clerk & Rutherford, 2000; Poutot & Blandin, 2015). Understanding these misconceptions is central for educators, as they can

significantly affect students' ability to grasp more complex concepts later in their studies (Tomara et al., 2017).

There are many tests that can be used to identify students' misconceptions before physics instruction. The most used is the Force Concept Inventory (FCI). The original version of the FCI was published in 1992 (Hestenes et al., 1992) and about half of the FCI questions were taken from the Mechanics Diagnostic Test (MDT) (Halloun & Hestenes, 1985). The MDT was first published in 1985, and the purpose of the test was to ascertain students' knowledge and understanding of Newtonian mechanics. Initially, it was administered in an open-answer form to introductory-level college students. From this implementation of the test, recurrent student alternative conceptions were identified, and a multiple-choice version was created, which contained the most common open-ended answers as choices.

Various versions of this multiple-choice test were administered to more than 1,000 college students, and the validity and reliability were established in different ways. For instance, the test was examined by several physics professors and graduate students, and interviews were conducted.

The developers of the 1992 version of the FCI stated that 'the Inventory [FCI] has the advantage of supplying a more systematic and complete profile of the various misconceptions (Hestenes et al., 1992). They did not, however, repeat the lengthy procedures to establish test validity and reliability for the FCI, limiting their activity in this direction to comparing student performance in the FCI and in interview situations. Students' interviews revealed that some American students, even though they are native English speakers, exhibited moderate to severe difficulty understanding the English text of the inventory. In most cases, the difficulty could be traced to overlooking the critical role of "little words" such as prepositions in determining meaning. Consequently, they discarded two interesting problems from their original version of the Inventory because they were misread (Hestenes et al., 1992).

A revised version of the FCI was developed in 1995 (Hestenes & Halloun, 1995). This revised version has 30 questions whereas the original FCI had only 29 questions. The 1995 version of the FCI has fewer ambiguities and a smaller likelihood of false positives i.e. correct answers for incorrect reasons as indicated by one of its authors (Hake, 1998). This version is up to date and is the version which was used in this research.

The FCI has been validated as an effective diagnostic tool for assessing student understanding in various educational contexts. Studies have demonstrated that the FCI can reliably identify misconceptions across diverse student populations,

including high school and college students (Poutot & Blandin, 2015). The pre-instruction administration of the FCI allows educators to gauge students' initial understanding and tailor instruction accordingly. This diagnostic capability is particularly vital in the context of peer instruction, where addressing misconceptions early can enhance the effectiveness of collaborative learning.

A complete taxonomy of these misconceptions can be found in the literature and is presented in the methodology chapter (Bani-Salameh, 2017a; Hestenes et al., 1992; Martín-Blas et al., 2010; Savinainen & Scott, 2002).

Using this taxonomy, A method of dominant misconception was proposed and used by Blas et al (Martín-Blas et al., 2010). To consider any incorrect answer to be dominant, it must have more than 50% of the total number of incorrect answers for that question. Blas et al. in Spain found the dominant misconceptions to be universal among students with varying academic backgrounds. This study indicated that despite differences in academic profiles, there was a remarkable correlation in the dominant incorrect answers given by different groups of students. The findings imply that these misconceptions are deeply rooted and persist regardless of the students' educational experiences.

A simillar study was conducted in Saudi Arabia and confirmed that dominant misconceptions are universal (Bani-Salameh, 2017a). This confirmation was based on the remarkable correlation found in the dominant incorrect answers across different groups of students studied by Martín-Blas et al. and the Saudi study. Despite the differences in the backgrounds and countries of origin of the students, similar patterns of dominant incorrect answers emerged, indicating that these misconceptions are not confined to a specific demographic. This consistency across diverse groups suggested that the misconceptions related to force and motion are widespread and not influenced by cultural or educational differences.

However, the universality of these misconceptions raised questions about the language and cultural factors that may influence students' understanding of physics. Research has shown that students from different cultural backgrounds may interpret physics concepts differently, influenced by their prior experiences and educational contexts (Aikenhead, 1996).

The FCI test can also be used to evaluate instruction by being administered twice to the same group of students: once before instruction and then after instruction, and calculating the learning gain.

Even though there are many countries worldwide whose language of instruction is not their native language, few studies have explored the impact of learning physics in a second language on students’ understanding. For example, a study

conducted in Saudi Arabia found a weak correlation between learning gain as indicated by the FCI and learning in a second language (Bani-Salameh, 2018)Nevertheless, this study dealt with learning with traditional methods, where students are mainly listeners, and not with active learning, where students are involved more in language when reading and discussing with instructors and their peers.

In the context of Sultan Qaboos University, where students are bilingual, the administration of the FCI in both Arabic and English allowed for understanding of how language influences students' grasp of physics concepts.

2.4 Teaching Methods, Learning Gains and Attitude

Physics Education Research has shown that the FCI is not only effective for identifying students' misconceptions but also helps as a useful tool for evaluating the effectiveness of different teaching methods by administering it twice before and after physics instruction. Research, which utilised the FCI has demonstrated that peer instruction can significantly enhance students' conceptual understanding of physics. For instance, Hake, (1998) conducted a meta-analysis of various instructional methods and found that courses using interactive engagement techniques, including peer instruction, resulted in significantly higher normalised learning gains on the FCI compared to traditional methods.

Another study by Deslauriers et al., (2011) found that students in a peer instruction class scored significantly higher on the FCI than their peers in a traditional lecture class, with normalised gains of 0.73 compared to 0.23, respectively. This substantial difference highlighted the effectiveness of interactive teaching methods in promoting conceptual understanding.

Similarly, a meta-analysis by Freeman et al., 2014 highlighted the positive impact of active learning strategies, including peer instruction, on student performance across various disciplines. The analysis indicated that active learning methods frequently outperformed traditional lectures, emphasising the need for a shift in physics education to enhance student learning outcomes.

However, most of these comparative studies were conducted in the US, and similar studies are needed in different language and cultural contexts.

Moreover, research has shown that teaching methods can significantly influence students' attitudes toward physics, which can significantly affect their engagement and persistence in the subject (Madsen et al., 2015). Positive attitudes are associated with higher levels of motivation, increased effort, and

improved academic performance, while negative attitudes can lead to disengagement (K. K. Perkins et al., 2008; Woo et al., 2022).

One of the most widely used tools for evaluating students' attitudes in the physics domain is the Colorado Learning Attitudes about Science Survey (CLASS). Developed by (Adams et al., 2006) CLASS is designed to evaluate students' beliefs and attitudes about physics and their learning processes.

A study by Zhang et al., (2017) utilized CLASS and revealed that interactive teaching methods, such as peer instruction, lead to a more positive attitude toward the subject compared to traditional lecture-based approaches.

However, interactive teaching methods were not always associated with positive shifts in students' attitudes, suggesting that the teaching methods or course content may not effectively foster a deeper understanding or appreciation of physics, leading to a deterioration in students' attitudes towards the subject (Slaughter et al., 2011).

As such, understanding and measuring these attitudes is crucial for educators aiming to foster a more positive learning environment and improve student outcomes.

2.5 Student-Student and Student-Teacher Interactions

Effective communication is the basis of successful peer instruction. Research has shown that collaborative learning environments, where students engage with one another, enhance critical thinking and problem-solving skills (Johnson & Johnson, 1975).

Student-student interactions are fundamental to the learning process. Vygotsky's social constructivist theory suggests that learning is a social activity, and interactions with peers can facilitate cognitive development (Vygotsky, 1978). In bilingual contexts, these interactions are particularly crucial as they provide opportunities for language practice and cultural exchange (Mateus, 2014).

Studies have shown that peer interactions can facilitate language acquisition, particularly when students are encouraged to communicate in both their native language and the targeted language (Mateus, 2014). This bilingual dialogue not only improves language proficiency but also enriches the learning experience by allowing students to express scientific concepts in a way that is culturally relevant and personally meaningful (Rojas-Drummond et al., 2013).

Additionally, code-switching between two languages in peer interactions where students may be learning in a second language can create a supportive

environment for language use, thereby enhancing fluency and confidence (Sakaria & Priyana, 2018).

Moreover, the cultural dimensions of student-student interactions cannot be overlooked. According to Hofstede's (1986) cultural dimensions theory, different cultures have varying approaches to communication, collaboration, and conflict resolution. Research has shown that understanding these cultural differences can lead to more effective communication and collaboration among students (Chima Abimbola Eden et al., 2024).

While student-student interactions are crucial, the role of student-teacher interactions is equally important. Teachers serve as facilitators of learning, guiding students through complex scientific concepts and fostering an inclusive classroom environment.

Research indicates that effective teacher-student interactions can significantly enhance students' motivation and engagement in science. For example, a study by Black and Wiliam highlights the importance of formative assessment and feedback in promoting student learning (Black Paul & Wiliam Dylan, 1998).

Furthermore, the language used by teachers during instruction can influence students' participation and comprehension. According to the work of Cummins, teachers who incorporate a culturally responsive pedagogy and utilize students' native languages in instruction can create a more inclusive learning environment (Cummins, 1992). This approach not only confirms students' linguistic identities but also facilitates their engagement with scientific content.

Moreover, students may feel pressure to adapt to the teaching language and the teacher's support in maintaining the native language can be important for academic success and emotional well-being (Creese & Blackledge, 2010).

Cultural factors also play a role in shaping these interactions; for instance, students from cultures that emphasize hierarchical relationships may be less likely to engage in open discussion with peers or instructors (Hofstede, 2001) Culturally responsive teaching involves recognising and incorporating students' cultural backgrounds into the curriculum, which fosters a sense of belonging and promotes engagement (Ashrafova, 2024).

Research conducted by Hattie & Timperley, (2007) suggests that feedback and communication between students and teachers are fundamental for learning. Understanding the nuances of these interactions within a culturally diverse classroom can provide insights into how to optimise peer instruction for improved learning outcomes.

In Sultan Qaboos University, where the application of PI is relatively new, it is essential to examine how language and cultural factors influence interactions during peer instruction.

2.6 Perspectives on Peer Instruction

The perceptions of both students and teachers regarding peer instruction play a significant role in its implementation and effectiveness. Research has shown that positive attitudes toward peer instruction can enhance student engagement and motivation (Dosoftei & Alexa, 2024; Knight & Brame, 2018). However, these perceptions are often shaped by language and cultural factors. For instance, students who feel confident in their language abilities may be more inclined to participate actively in peer instruction, while those who struggle with language may feel apprehensive (Q. Zhang et al., 2024).

Teachers' perspectives are equally important, as their beliefs about the value of peer instruction can influence their instructional choices and the support, they provide to students (Flint et al., 2024). Understanding how cultural factors influence teachers' attitudes toward collaborative learning can inform professional development and training programs designed to enhance the effectiveness of peer instruction.

2.7 Summary

The literature indicates that language and cultural factors can influence the implementation and effectiveness of peer instruction in physics education. These factors affect students’ conceptual understanding, interaction dynamics, and perceptions of peer instruction. As educational institutions like Sultan Qaboos University strive to foster collaborative learning environments, it is essential to consider these influences in the design and implementation of peer instruction strategies. Future research should continue to explore the nuanced relationships between language, culture, and peer instruction to better support diverse student populations in achieving their learning goals.

Chapter 3
Research Methodology

The aim of this research was to explore how language and cultural factors impact the implementation of peer instruction in Physics at Sultan Qaboos University. To achieve this goal, a case study approach was employed to investigate the specific context of Sultan Qaboos University and gain a deeper insight into the research problem. This case study was enhanced by a mixed-methods approach, which integrated both quantitative and qualitative data collection and analysis techniques. The chosen design was intended to enable an investigation of the research questions by providing both statistical evidence and detailed narratives that illuminate the findings.

This chapter outlines the methodology employed in this study, detailing the research design, data collection methods, data analysis procedures, ethical considerations, and the research limitations.

3.1 Research Design

The main research design for this investigation involved a case study approach selected for its ability to thoroughly examine the context in which peer instruction is applied in the Physics department at Sultan Qaboos University. A case study methodology is ideal for analysing complex educational contexts and phenomena where multiple factors interact since it enables the researcher to delve into real-world scenarios in detail and capture the nuanced interplay of various elements (L. D. Cook & Kamalodeen, 2020).This case study design allows for the exploration of how language and cultural factors affect the application and effectiveness of peer instruction, aligning the research within a well-defined, real-world context that offers meaningful insights and context-specific understanding.

To further improve the robustness and depth of the case study, a mixed-methods approach was integrated. This approach was selected to leverage the strengths of both qualitative and quantitative methods. Therefore, enabling the researcher to explore the research questions in a comprehensive manner (Schoonenboom & Johnson, 2017). The complication of studying the effect of language and cultural factors on educational methods, such as peer instruction, requires a multilayered approach that can capture both measurable quantitative results and the subjective qualitative experiences of participants (Wei, 2022).

Moreover, integrating a mixed-methods approach within the case study design confirms that the study does not depend only on numerical data or subjective interpretations but instead combines these elements to provide a richer and more comprehensive understanding (Plano Clark, 2019).

3.2 Research Questions and Methods

The mixed-methods approach employed in this study was specifically tailored to address the research questions under investigation, ensuring comprehensive data collection and analysis that effectively address each question. The alignment of research questions with the chosen methods is as follows:

Research Question 1: How do language and cultural factors affect students' conceptual understanding of physics?

Method Used: The Force Concept Inventory (FCI), available in both Arabic and English, is a quantitative tool used to measure students' conceptual understanding and provide numerical data to analyse the quantitative effect of language and cultural factors on learning outcomes.

Rationale: The use of this quantitative assessment enabled objective measurements and statistical analysis of student performance, directly addressing the research question by quantifying the impact of language and cultural variables.

Research Question 2: How does the teaching method affect students' learning gain and attitude toward physics?

Method Used: A half-FCI assessment, a shorter version of the FCI, was used to assess students' learning gains during online learning.

Rationale: Due to online learning, it was not easy to encourage students to conduct the full-length FCI. Therefore, it has been decided to use the Half FCI.

Method used: Think-aloud Student Interviews, which provided insight into the cognitive processes students undergo when engaging with different instructional modes.

Rationale: Due to the weak participation of students in the online FCI, it has been decided to conduct think-aloud interviews to support the findings of the FCI and give an in-depth understanding of students' reasoning in both Arabic and English.

This integration revealed how different modes of instruction can be influenced by language and cultural factors.

Method used: Colorado Learning Attitudes about Science Survey (CLASS), which was utilised to assess shifts in students' attitudes toward learning physics, capturing how language and cultural factors may affect their attitudes and beliefs about learning physics.

Rationale: To measure students' attitudes toward learning physics, which can contribute to their effective learning, and to compare the two instructional methods.

Research Question 3: How do language and cultural factors affect student-student and student-teacher interactions?

Methods Used: Semi-structured interviews with instructors provided immediate narratives of how language and cultural factors affect classroom interactions. Additionally, semi-structured interviews with students complemented the instructors' perspectives by adding depth and confirming observations.

Rationale: Using qualitative methods was fundamental to exploring the nuanced dynamics of classroom interactions that cannot be quantified. Interviews enabled the collection of rich, descriptive data, revealing how language and cultural contexts influence student-student and student-teacher interactions.

Research Question 4: What are the students' and teachers' perspectives about peer instruction?

Methods Used: Semi-structured instructors and students Interviews were used to gather detailed qualitative perspectives on the effectiveness, challenges, and benefits of peer instruction as experienced by both groups.

Rationale: Collecting qualitative data through semi-structured interviews was necessary to capture subjective experiences and insights beyond measurable results. This method provided a deeper understanding of how language and cultural factors affect perceptions of teachers and students regarding peer instruction.

3.3 Participants and Sampling

The participants in this study included students and instructors of introductory Physics courses at Sultan Qaboos University. The student participants included

those registered in undergraduate introductory Physics courses that adopted either traditional teaching (for Engineering students) or peer instruction (for Science, Science Education, and Agriculture students) as a teaching approach. In high school, these students were taught physics primarily in Arabic, but with English symbols and equations. They have some background in English as their second language. The admission criteria vary by college. To be admitted into the College of Engineering and subsequently register for the Physics for Engineering course, students must achieve a minimum grade of 65% in mathematics, physics, chemistry, and basic English language in high school. To be admitted into the Science Education program in the College of Education, Students must achieve a minimum grade of 65% in mathematics, physics, chemistry, biology, and basic English language in high school. However, students in the Colleges of Science and Agriculture are not required to have physics as a compulsory subject for admission (SQU, 2021). Most students then take a one-year foundation program, comprising Mathematics, Information Technology, and the English language, before commencing their undergraduate studies. Details of the foundation program were given in Chapter 1.

The instructor participants were faculty members teaching introductory Physics courses and have experience with both teaching approaches, namely, traditional teaching and peer instruction. These instructors provided detailed insights into the teaching methodologies, student engagement, and the challenges they faced while implementing peer instruction within the language and cultural context of the university under study.

Purposive sampling was employed to ensure that the sample was representative and provided comprehensive data to address the research questions. This method was chosen to carefully select participants who could provide the most relevant and meaningful insights related to the study's focus on language and cultural effects. This approach enabled a deeper understanding of how these factors influenced the learning process across a wide range of experiences.

The selection criteria for student participants included:

1. Enrollment in an introductory Physics course, either Physics I for Engineering or Physics I for Science. That course can either incorporate traditional teaching or peer instruction as a teaching strategy.
2. Willingness to participate in surveys, interviews, and think-aloud sessions.
3. A range of language proficiencies (non-native Arabic speakers) to explore language dynamics in their learning and interaction.

The selection criteria for instructor participants included:

1. Experience in teaching Physics introductory courses at Sultan Qaboos University using either traditional teaching or peer instruction.
2. Availability and willingness to share their experiences and perspectives about their teaching in the interviews.
3. Experience with various student groups to provide comprehensive insights into student-teacher and student-student interactions affected by language and cultural elements.

These criteria ensured that the participants selected for the study were well-positioned to provide detailed, contextually rich data that are aligned with the research questions and objectives.

3.4 Data Collection Methods

This study employed a mixed-methods data collection strategy to comprehensively investigate the impact of language and cultural factors on the implementation of peer instruction in Physics at Sultan Qaboos University. This strategy combined quantitative assessments to acquire objective, measurable data with qualitative methods to provide deeper insights into the experiences and perceptions of students and instructors. The following is a detailed description of the data collection methods and procedures for each research question.

3.4.1 Quantitative Data Collection

3.4.1.1 Force Concept Inventory (FCI)

The Force Concept Inventory (FCI) 95 version was used to measure students' conceptual understanding of fundamental Physics concepts (Hestenes & Halloun, 1995). The FCI is a widely recognized multiple-choice test designed to identify common misconceptions about Newtonian mechanics. In this study, the FCI was administered in Arabic and English before any university physics instruction to evaluate students' conceptual understanding and determine how language and cultural factors influenced their learning outcomes.

The FCI was distributed as a paper format during designated laboratory sessions in SPRING 2020 semester. The pre-test was conducted at the beginning of the semester. The data collected from the FCI was scored and analyzed to measure students' conceptual understanding.

3.4.1.2 Half FCI

A half-length version of the FCI was used to assess learning gains without overburdening students with the lengthy FCI test. Due to the circumstances of online learning, we found that it is more convenient to administer the Half FCIs rather than the full FCI. This version was developed by Han et al., 2015 and contains 14 multiple-choice questions and maintains the reliability of the full FCI while providing focused insights into the impact of different teaching modes on conceptual understanding. A comparison between the two Half FCIs and the corresponding questions from the full-length FCI is shown in Table 3-1. Three FCI questions (2, 26, and 28) were used on both half-length tests for test equating purposes.

Question No	Pre-Half FCI	Post-Half FCI
1	2	2
2	15	4
3	5	30
4	6	7
5	8	18
6	9	21
7	10	22
8	11	23
9	13	24
10	12	25
11	26	26
12	17	14
13	19	20
14	28	28

Table 3-1 A comparison between pre- and post-tests of the Half FCI and the corresponding questions adapted from the full-length FCI.

The Half FCI was administered twice: at the beginning of the semester, prior to any physics instruction, and at the end of the semester. This enabled the assessment of learning gains, contributing to an understanding of how language and cultural factors influenced students' conceptual understanding throughout the course.

3.4.1.3 Colorado Learning Attitudes about Science Survey (CLASS)

The Colorado Learning Attitudes about Science Survey (CLASS), developed by Adams et al., 2006, is a tool designed to evaluate students' attitudes and beliefs about physics and their learning experiences in the subject. It aims to explore

various aspects of students' attitudes towards physics and their approach to learning it.

CLASS, which was created through a rigorous validation process, can distinguish between the attitudes and beliefs of expert physicists and novice students by probing students' beliefs about physics and learning physics through a series of statements. The survey was designed to produce responses that reflect the perspectives of both groups, allowing for a comparison of expert-like and novice-like beliefs. Expert physicists, who have extensive experience in teaching and working with students, provide a benchmark for what constitutes expert beliefs. Novice students, on the other hand, may hold misconceptions or less coherent ideas about learning physics.

The complete survey is presented in Appendix B. It consists of 42 statements that students respond to using a five-point Likert scale, ranging from “strongly disagree” to “strongly agree”. These statements were developed to be clear and concise, ensuring they are understandable to a broad range of students, including those without prior physics experience.

There are many useful ways to use CLASS data. One can look at the pre-results and their correlation with student learning, course selection, retention, gender, age, major, etc. One can also look at the shift in attitudes and beliefs over a semester to determine correlations between various teaching practices and students’ attitudes.

In this research, CLASS was used to measure the shift in students' attitudes toward learning physics. The CLASS survey was administered twice during the semester: at the beginning (pre-survey) and the end (post-survey). Students were provided with explicit written instructions in Arabic to complete the survey through an online platform. The data was analysed using the template provided by the authors to identify shifts in attitudes and correlate them with teaching methods. To ensure students understood the questions well, an Arabic version of CLASS, which was developed by Alhadlaq et al., 2009 was used.

3.4.2 Qualitative Data Collection

3.4.2.1 Think-Aloud Student Interviews

Think-aloud interviews were conducted to acquire students' cognitive processes as they solved three FCI questions in Arabic and English. In these interviews, students were asked to express their thought processes while solving the questions. This approach provided rich qualitative data that supported the

quantitative data from the Half FCI, revealing how students navigated language and cultural influences in real time while answering the questions.

Students who were willing to participate in the think-aloud interviews were informed of the purpose of the interview and were encouraged to speak freely and express their thoughts without concern for correctness. The interviews were audio-recorded and transcribed for subsequent analysis. The think-aloud interviews were particularly useful in identifying specific language-related challenges and cultural factors that affected the students' comprehension and problem-solving strategies.

Questions for Think Aloud Interviews

2. Two metal balls are the same size, but one weighs twice as much as the other. The two metal balls roll off a horizontal table with the same speed. In this situation:

A. both balls hit the floor at approximately the same horizontal distance from the base of

the table.

B. the heavier ball hits the floor at about half the horizontal distance from the base of the

table than does the lighter ball.

C. the lighter ball hits the floor at about half the horizontal distance from the base of the

table than does the heavier ball.

D. the heavier ball hits the floor considerably closer to the base of the table than the

lighter ball, but not necessarily at half the horizontal distance.

E. the lighter ball hits the floor considerably closer to the base of the table than the

heavier ball, but not necessarily at half the horizontal distance.

ANSWER: A

26. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed "vo". If the woman

doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:

A. with a constant speed that is double the speed "vo"

B. with a constant speed that is greater than the speed "vo", but not necessarily twice as great.

C. for a while with a speed that is constant and greater than the speed "vo", then with a speed that increases thereafter.

D. for a while with an increasing speed, then with a constant speed thereafter.

E. with a continuously increasing speed.

ANSWER: E

28. In the figure below, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching each other

A. neither student exerts a force on the other.

B. student "a" exerts a force on student "b", but "b" does not exert any force on "a".

C. each student exerts a force on the other, but "b" exerts the larger force.

D. each student exerts a force on the other, but "a" exerts the larger force.

E. each student exerts the same amount of force on the other.

ANSWER: E

Think Aloud Interview Protocol:

First, show the students the three questions in English if they have conducted the English Half FCI and vice versa. Then, ask them to solve each one individually.

Second: Ask them if they did not understand anything in the question.

Third: Ask them about the physics concept involved in the question.

Fourth: Ask them if the instruction (Peer/Traditional) helped them solve these questions or what helped them grasp that particular concept the most. Instruction, discussion, or self-study?

Fifth: Ask them if they faced any issue with language in the (Arabic/English) pre or post-test in general

Sixth: Ask them if they try to translate physics problems before they solve them in general.

Seventh: Repeat the same process for the Arabic version but with shuffled multiple-choice options.

3.4.2.2 Teachers' Interviews

Semi-structured interviews with teachers were conducted to gain insights into their perceptions of language and cultural factors impacting peer instruction. These interviews covered topics such as the challenges and benefits of using peer instruction, observed student interactions, and strategies instructors applied to overcome language and cultural barriers.

Teachers' Interview Protocol

The interview protocol was designed to cover a range of topics and questions that would allow the teachers to share their insights, challenges, and strategies related to implementing peer instruction in physics introductory courses. The protocol consisted of open-ended and semi-structured questions to encourage the participants to provide detailed and comprehensive responses.

1. **Introduction:** The participants were initially asked to provide some background information about their teaching experience and their familiarity with both traditional teaching and peer instruction

2. **Implementation of Peer Instruction:** The participants were asked about their experiences in implementing peer instruction, including the strategies they used,

the challenges they encountered, and the benefits they observed for teachers and students.

3. **Language and Cultural Factors:** The participants were asked about their views on the effect of language and cultural factors on implementing peer instruction. This included exploring the role of language proficiency and cultural norms in the effectiveness of peer instruction.

4. **Support and Resources:** The participants were asked about the support and resources they received or needed to implement peer instruction effectively. This included discussing the availability of training, materials, and technology.

5. **Recommendations and Future Directions:** The participants were asked to provide recommendations for improving the implementation of peer instruction and physics education in general, considering language and cultural factors.

The Questions for Instructors' Interview

- From your perspective, how do you describe PI?
- How did you know about PI? how many semesters did you teach with PI and how many semesters did you teach with traditional teaching?
- What benefits did you get from PI?
- What challenges or barriers do you face while teaching with PI and how do you try to overcome them?
- If you have the choice: would you continue teaching with PI or would opt for other teaching methods? Why?

Institution:

- What kind of support do you get from colleagues, department and university to be able to teach with PI effectively?
- What other support do you need to overcome challenges associated with PI from colleagues, department and university to facilitate challenges associated with PI?

(i.e. Support might include: technology, special training, advice from experts, teaching assistances, classroom settings etc.)

Students:

- This course might be the first exposure for students to active learning. How do they react to PI? What impressions do you get usually from students? Are they happy with this style of teaching or they resist it? How well, do you think, they adapt to PI? Are they engaged in class discussions effectively? Are they motivated to do the pre-reading assignment before class?
- Students perceive physics as a difficult subject during high school time and it is not related to real life, from your experience with both traditional teaching and PI: How do you compare effects of teaching style on this attitude towards learning physics compared to traditional teaching?
- Are there any constraints from cultural and language sides (e.g. students used to passive learning at school and rarely engaged in class discussions, being English is not their first language: do they use Arabic or English to discuss with their peers and the instructors?) Do you think this affects their learning process? How do you help them to overcome any constraints if they exist?

3.4.2.3 Student Interviews:

Semi-structured interviews with students complemented the quantitative data by exploring their personal experiences with peer instruction. Questions of students' interviews focused on how language and cultural context influenced their engagement, interaction with peers and teachers, and their overall learning experience.

Students' Interview Protocol

The interview protocol for students was designed to explore various topics and questions. First, students were asked about their perceptions of peer instruction, including their understanding of its purpose and benefits. Additionally, questions were asked to assess students' experiences with peer interaction, such as their level of engagement, comfort, and satisfaction with working in groups. Moreover, students were encouraged to share any challenges or barriers they faced related to language and cultural factors when participating in peer instruction.

Several strategies were implemented to conduct interviews with sensitivity and cultural proficiency. Firstly, language support was provided if needed by the bilingual interviewer/researcher. Moreover, more explanation was provided if the student had not been previously taught by PI. Additionally, efforts have been made to create a comfortable environment for students to share their thoughts and experiences. This was achieved by emphasising confidentiality, ensuring

privacy during interviews, using open-ended and non-judgmental questions and conducting the interviews after the students got their final exam results.

Students' Interview Questions

Peer instruction is a teaching method that involves students preparing for class by doing pre-class reading and answering some related questions before the lecture. Then, in class, the instructor poses some multiple choice questions, which the students answer individually first and then by discussion with their colleagues.

The following interview questions are meant to probe any cultural and linguistic opportunities or challenges that you might face while you are taught by peer instruction.

Cultural opportunities and challenges:

1. Have you heard about Peer Instruction before? If yes, when and where?

2. Have you been taught by peer instruction at school?

3. Have you been taught by Peer Instruction at the foundation program?

4. What method did you expect to learn physics at the university?

5. What do you think is the most effective way of learning physics? Why?

6. How do you perceive physics teaching difference in school and university?

8. How different are the students' and teachers' interactions in university from school?

8. Do you prefer to solve physics problems alone or with colleagues? Why?

9. Do you understand physics better when you work alone or with colleagues? Why?

10. Do you read the textbook before the lecture? Why?

11. During the physics class, do you prefer to sit and listen to the instructor explaining the physics or work out and discuss physics with your colleagues? Why?

12. To what degree do you contribute to in-class discussions? Why?

13. Do you feel confident when you participate and speak during class discussions? Why?

14. During the physics class, do you understand physics better when you participate in class discussions with your colleagues or when you only focus on listening and taking notes? Why?

Linguistic opportunities and challenges:

15. In what language did you study physics at school?

16. What is your experience about learning physics in English at the university and how did you cope with that?

17. To what degree have the English courses that you have studied in the foundation program helped you in understanding physics at the university?

18. In what language do you prefer to learn physics? Why?

19. Do you have a preference to have an Arabic or a non-Arabic speaking instructor? Why?

20. In what language do you prefer to discuss physics with your instructor? Why?

21. In what language do you prefer to discuss physics with your colleagues? Why?

22. Have you faced any challenges in reading the textbook before the lecture because it is in English? What did you do to overcome these challenges?

23. Does reading the material before the lecture help you facilitate the linguistic challenge and understand the lecture better.

24. Does Peer Instruction make it easier or harder to learn physics in English. Why and how?

25. Do you have any suggestions or comments regarding learning physic in English or by Peer Instruction?

3.4.2.4 The Procedure of the Interviews:

Interviews were conducted via videoconferencing. The interviews followed flexible guidelines to allow for in-depth exploration of relevant topics while enabling participants to share their perspectives openly. All interviews were recorded with consent and transcribed verbatim for analysis. Thematic analysis was then applied to identify recurring patterns and themes that highlighted the impact of language and cultural factors on peer instruction.

3.5 Data Analysis Procedures

The data analysis procedures for this study involved different yet complementary methods for quantitative and qualitative data, ensuring a thorough consideration of the research questions. By employing both types of analysis, the study provided a comprehensive understanding of how language and cultural factors influenced peer instruction in Physics courses at Sultan Qaboos University.

3.5.1 Quantitative Data Analysis

3.5.1.1 Force Concept Inventory (FCI) Analysis

The pre-test FCI data was scored based on the number of correct responses to measure conceptual understanding and to identify and classify the common-sense misconceptions before the start of any physics instruction (Hestenes et al., 1992). A complete code and taxonomy of these misconceptions can be found in literature and is presented in Table 3-2 and Table 3-3.

Code	Description
K1	Position-velocity undiscriminated
K2	Velocity-acceleration undiscriminated
K3	Nonvectorial velocity composition
K4	Ego-centered reference frame
I1	Impetus supplied by 'hit'
I2	Loss/recovery of original impetus
I3	Impetus dissipation
I4	Gradual/delayed impetus build-up
I5	Circular impetus
AF1	Only active agents exert forces
AF2	Motion implies active force
AF3	No motion implies no force
AF4	Velocity proportional to applied force
AF5	Acceleration implies increasing force
AF6	Force causes acceleration to terminal velocity
AF7	Active force wears out
AR1	Greater mass implies greater force
AR2	Most active agent produces greatest force
CI1	Largest force determines motion
CI2	Force compromise determines motion
CI3	Last force to act determines motion
CF	Centrifugal force
Ob	Obstacles exert no force
R1	Mass makes things stop
R2	Motion when force overcomes resistance
R3	Resistance opposes force/impetus
G1	Air pressure-assisted gravity
G2	Gravity intrinsic to mass
G3	Heavier objects fall faster
G4	Gravity increases as objects fall
G5	Gravity acts after impetus wears down

Table 3-2 Codes that are used to identify misconceptions in FCI (Bani-Salameh, 2017)**.**

	A	B	C	D	E
1	G3				
2		G3		G3	
3	AF6	AF5, G4		G2	G1
4	AR1		Ob	AR1	
5	Ob		I1, I5, AF2	I1, I5, AF2	I1, I5, AF2, CF
6	I5		CF	CI2, CF	CF
7	I5		CI2, CF	I2, I5, CF	CF
8	CI3		I2	I4	I2
9		CI3	K3		
10		I4		I4	
11	Ob, G1	I1, Ob	I1		G2
12	CI2		I3	I3, G5	
13	I3	I3, G4, G5	I3		G2
14	K4	K4	CI2		I3, G5
15		AR1	AR2	AF1	Ob
16		AR1	AR2	AF1	Ob
17	CI1			CI1, G1	AF1
18	AF1, Ob		I5	I5	CF
19	K2	K1	K1	K1	
20		K2	K2		
21	I2	CI3	CI2	I4	
22	AF4		AF7	AF6	AF7
23	I2		CI3	I2, I3	I4
24			I3		I3
25	R2	R2		R2	CI1
26	AF4	R2, R3	I4	AF6	
27	AF2, R1	I3, R1		I1	I4
28		AF1		AR1, AR2	
29	Ob		G1, G2	G1	AF3
30	AF1	I1		I1	I1

Table 3-3 A taxonomy of misconceptions probed by the FCI for each question (Bani-Salameh, 2017)**.**

Then, the method of dominant misconception, which was proposed by Martín-Blas et al. (2010), was applied so that to consider any incorrect answer to be dominant, it must have more than 50% of the total number of incorrect answers for that question.

3.5.1.2 Half FCI Analysis

The Half FCI data was scored based on the number of correct responses. The pre-test and post-test results were compared, and only matched responses were included in the analysis. These results were compared using the average normalised gain <g>, which is the ratio of the actual average gain <G> to the maximum possible average gain as follows

$$< g > = \frac{\%<G>}{\%<G>_{max}} = \frac{\%<S_f> - \%<S_i>}{100 - \%<S_i>} \quad \textbf{Equation 1}$$

Where the <> symbols indicate class average scores, and <*Sf*> and <*Si*> represent the final (post) and initial (pre) class averages, respectively.

This parameter can be used as an indicator of the effectiveness of the instruction method(Hake, 1998). Table 3-4 classifies courses according to <g> value:

Course Classification	Normalized Gain (<g>)
High Gain Courses	g ≥ 0.7
Medium Gain Courses	0.7 > g ≥ 0.3
Low Gain Courses	g < 0.3

Table 3-4 Learning gain classification.

Statistical analyses such as descriptive statistics (means and standard deviations) and inferential statistics (t-test or Mann-Whitney test) were used to determine whether the changes in conceptual understanding were significant. This helped to identify the impact of the teaching methods, highlighting the effect of language and cultural factors on students' learning outcomes.

3.5.1.3 Colorado Learning Attitudes about Science Survey (CLASS) Analysis

CLASS comprises 42 statements, with only 27 of these categorised into eight specific aspects of student thinking that are real-world connections, personal interest, sense-making, conceptual understanding, applied conceptual understanding, general problem solving, problem-solving confidence and problem-solving sophistication as listed in Table 3-5. Each category consists of four to eight statements, and together, these categories include 27 statements. The overall score includes these statements plus an additional nine statements. The remaining six, to complete the 42-statement survey, are statements that do not have an "expert" response or are not helpful in their current form. These statements are excluded from scoring to maintain the validity and reliability of the survey results.

Categories	Statements comprising category
Real World Connection	28, 30, 35, 37
Personal Interest	3, 11, 14, 25, 28, 30
Sense Making/Effort	11, 23, 24, 32, 36, 39, 42
Conceptual Connections	1, 5, 6, 13, 21, 32
Applied Conceptual Understanding	1, 5, 6, 8, 21, 22, 40
Problem Solving General	13, 15, 16, 25, 26, 34, 40, 42
Problem Solving Confidence	15, 16, 34, 40
Problem Solving Sophistication	5, 21, 22, 25, 34, 40
Not Scored	4, 7, 9, 31, 33, 41

Table 3-5 The categories of CLASS and the statement included in each category (Adams et al., 2006)**.**

The scoring of CLASS is done by determining, for each student, the percentage of responses for which the student agrees with the experts' view "percent favourable" and then averaging these individual scores to determine the average percent favourable. The survey is scored "overall" and for the eight categories listed in Table 3-5.

In this research, the CLASS survey data was analysed using an Excel template provided by the CLASS developers and available at www.physport.org. Responses were categorised according to the survey's pre-defined dimensions (e.g., personal interest, real-world connections, conceptual understanding, sense-making, problem-solving confidence, and applied conceptual understanding). A comparison of pre- and post-survey results was conducted to detect shifts in student attitudes toward Physics.

3.5.2 Qualitative Data Analysis

Thematic Analysis: A thematic analysis approach was employed to identify, analyse, and report patterns within the interview data. Themes were developed to capture the influence of language and cultural factors on peer instruction, student-student interactions, and student-teacher interactions. Specific attention was given to language barriers, cultural expectations, and their impact on learning and engagement. This analysis enabled the extraction of meaningful insights that explained the perspectives and experiences of both students and instructors within their educational context.

The interview data were analysed using thematic analysis (Braun & Clarke, 2006). Thematic analysis allows for the identification and exploration of patterns, themes, and meanings within the data. The following steps will be followed by data analysis:

1. Transcription: All interviews, including think-aloud student interviews and instructor and student semi-structured interviews, were audio-recorded with participants' consent and subsequently transcribed verbatim, ensuring the accuracy and completeness of the data.

2. Familiarisation: The researcher thoroughly read the transcripts to gain a deep understanding of the data and become familiar with its content.

3. Coding: The transcribed data was imported into qualitative analysis software (NVivo) for coding. Initial codes were generated by systematically labeling and categorizing meaningful segments of the data. This involved both deductive coding, based on the interview protocol, and inductive coding, allowing for the emergence of new themes.

4. Theme Development: The codes were grouped into potential themes, considering their relevance and significance to the research questions. The themes were refined and revised through an iterative process, ensuring they accurately represented the data.

5. Data Interpretation: The themes were interpreted, considering the broader context of the study and the relevant literature. This involved examining the relationships between themes, identifying patterns, and drawing conclusions.

6. Validation: The themes and interpretations were shared with the supervisors. This allowed for the supervisors' feedback and validation of the findings, enhancing the credibility of the study.

The coding process was conducted mainly by the researcher and revised by the supervisors to enhance the reliability and validity of the findings. Any discrepancies in coding were resolved through discussion and consensus. Finally, the findings were interpreted to uncover insights into the influence of cultural and language factors on students' experiences with peer instruction. This interpretation involved considering the context, participants' perspectives, and relevant theoretical frameworks to provide a comprehensive understanding of the research questions.

3.5.3 Integration of Qualitative and Quantitative Findings

Integrating the results from both quantitative and qualitative analyses ensured the validity and robustness of the research findings. The quantitative data provided a numerical foundation for understanding the impact of language and cultural factors on learning outcomes and attitudes. In contrast, the qualitative data enriched these findings with detailed narratives and personal experiences.

Integration involved cross-referencing patterns identified in the qualitative data with statistical trends from the quantitative analysis. For example, changes in students' conceptual understanding as revealed by the FCI were compared with themes from think-aloud interviews that described language-related difficulties or culturally influenced problem-solving approaches. Similarly, shifts in attitudes detected through the CLASS survey were aligned with student and instructor interview data that provided context and explanations for these changes.

3.5.4 Validity and Reliability

To ensure that the quantitative instruments used in this study provided consistent, accurate, and valid data, several rigorous measures were taken. These measures were designed to verify that the results could be trusted and appropriately reflected the research objectives.

Force Concept Inventory (FCI):

The FCI was selected as a data collection tool to assess students' understanding of fundamental concepts in mechanics. The rationale for using the FCI is its wide recognition and validation as an instrument for evaluating students' conceptual understanding including studies at Sultan Qaboos University (Koca & Sulaiman, 2021). The Arabic version of the FCI was also validated in previous studies (Bani-Salameh, 2018).

Half FCI:

The Half FCI was validated in previous studies and proved to produce similar learning gains as the full-length FCI (Han et al., 2016).

Colorado Learning Attitudes about Science Survey (CLASS):

The CLASS survey, which measures student attitudes toward learning science, has been shown to have reliable constructions in prior studies (Adams et al., 2006).

The Arabic version of CLASS was also validated in previous studies (Alhadlaq et al., 2009).

Moreover, ensuring the credibility and trustworthiness of qualitative data was essential for the robustness of the findings. The following strategies were employed:

Peer Reviewing:

Peer reviewing by the supervisors was used to provide an external check on the data analysis and interpretation. This helped to identify potential biases and strengthen the credibility of the findings. The researcher shared two translated think-aloud interviews, one translated student interview and one teacher's interview with the supervisors. The three of us coded the interviews separately and later discussed these codes, agreeing on specific ones. This external input ensured that the interpretations were grounded in the data and not solely influenced by the researcher’s perspectives.

Rich and Thick Description:

Providing rich and thick descriptions of the study context, participants’ experiences, and findings supported the transferability of the results to similar settings. Detailed information about participants’ experiences and backgrounds was included in the analysis to allow readers to understand the context in which the study was conducted thoroughly. The extensive use of direct quotes from participants reinforced the authenticity and depth of the qualitative data.

3.6 Ethical Considerations

Ensuring that all participants were fully informed and willingly participated in the study was a top priority. The following procedures were adopted to uphold informed consent:

Explanation of the Study: Prior to participation, all potential participants (both students and instructors) were provided with a detailed explanation of the study’s purpose, objectives, and the procedures involved. This information was shared through electronic information sheets and verbal briefings conducted before the interview began. These are listed in Appendix C.

Voluntary Participation: It was emphasised that participation in the study was entirely voluntary, and participants could withdraw at any time without consequence. This assurance helped maintain the participants’ autonomy and comfort throughout the process.

Written Consent: Written informed consent forms were provided to all participants. These forms outlined the study's nature, the expected time commitment, the type of data to be collected, and how the data would be used. Only those who signed and returned the consent forms were included in the study.

Moreover, protecting participant confidentiality and ensuring data security were central to the study's ethical approach. The following measures were implemented:

Anonymity: All participants were assigned unique identification codes to ensure the anonymity of their responses in both qualitative and quantitative datasets. This ensured that personal identifiers were removed from any published or shared findings.

Secure Data Storage: The data collected during the study were stored on password-protected computers and secure servers, with access limited to the researcher only. Hard copies of all materials were stored in secure facilities.

Confidential Interviews: To maintain confidentiality, interviews and think-aloud sessions were conducted in private, secure locations. Audio recordings were stored securely, and transcripts were anonymised during the transcription process.

Pseudonyms: In reporting qualitative findings, pseudonyms were used for all participants to ensure that their identities remained confidential.

Ethical Approvals Obtained: Before data collection began, ethical approval was obtained from the University of Leeds to ensure that the study adhered to institutional and ethical standards for conducting research involving human participants:

3.7 Limitations of the Study

Despite the comprehensive approach of this study, certain limitations were recognised in the research design, data collection, and analysis processes.

Case Study Design Limitations: The use of a case study design limited the generalizability of the findings. The research focused specifically on the Physics department at Sultan Qaboos University, which means that the results are inherently tied to the unique language, cultural, and educational context of this institution. While this provided rich, context-specific insights, it may not be

representative of all educational institutions or applicable to different cultural or linguistic settings.

Participant Bias: There was a potential for participant bias, particularly during the interviews. Some participants may have provided socially desirable responses, especially when discussing language and cultural issues that could be seen as sensitive or controversial.

Time Constraints: The data collection process was conducted within the confines of a semester, which limited the ability to track the longer-term impacts of peer instruction on student learning and attitudes. A longer timeframe might have revealed additional trends and insights that were not captured in this study.

Instrument Limitations: Although the Force Concept Inventory (FCI) and CLASS survey are well-established tools, their implementation in a non-Western, bilingual context could introduce challenges in interpretation. Moreover, the Half FCI cannot be used to provide a full understanding of students' misconceptions and its use is limited to evaluating the learning gains (Han et al., 2016).

The impact of COVID-19: The transition to online learning could significantly affect the teaching methods used. Moreover, it greatly reduced the responses to online surveys.

The impact of the major of students: Traditional teaching students were mainly Engineering majors, while Peer Instruction students were from the colleges of science, science education, and agriculture. This was outside the researcher's control and could have impacted on the results of the FCI and CLASS.

Depth of Qualitative Data: While qualitative interviews provided rich insights, their depth was dependent on participants' willingness to share openly and honestly. In some cases, participants may have been hesitant to express their full opinions due to cultural norms or concerns about maintaining anonymity, which could have affected the comprehensiveness of the data.

Researcher Bias in Qualitative Data: The possibility of researcher bias in interpreting qualitative data was a limitation. Although strategies such as peer reviewing were employed, the analysis could still reflect subjective interpretations.

Short-Term Perspective: The study's focus on data collection over a single semester provided a snapshot view of the impact of peer instruction. Longitudinal data would be required to gain a deeper understanding of how language and cultural factors influence long-term learning gains and attitudes.

3.8 Summary

This chapter outlines the comprehensive methodology employed in this study, which aims to investigate the effects of language and cultural factors on the implementation of peer instruction in Physics at Sultan Qaboos University. The research adopted a case study design, enriched by a mixed-methods approach that integrated both quantitative and qualitative data collection methods to provide a robust and multi-faceted exploration of the research questions.

With the methodology established, the study now proceeds to the next chapter, which presents the results and findings obtained from the data collection and analysis. This upcoming chapter will provide detailed answers to the research questions, incorporating both quantitative results and qualitative themes to offer a well-rounded understanding of the study's outcomes.

Chapter 4
Dominant pre-existing Misconceptions

The purpose of this chapter is to address Research Question 1: How do cultural and linguistic opportunities and challenges impact students' conceptual understanding of physics? To achieve this, the chapter presents findings from the analysis of pre-FCI assessments conducted in both Arabic and English. This includes an overview of summary statistics of students' overall FCI scores, as well as an analysis of students' performance on individual FCI questions administered in both languages, highlighting any differences or similarities in their responses and misconceptions. Finally, the dominant misconceptions held by students before any university physics instruction will be identified with a particular emphasis on how these misconceptions may vary depending on the language of the FCI.

4.1 Pre-FCI Assessment Results

This section provides an overview of students' overall FCI scores before any physics instruction and its dependence on the language of the test, whether it is Arabic or English. The test was conducted in paper format during the tutorial session. The participants were students of Physics 1 for the Engineering course and students of Physics I for the Science course. Each course is further divided into five groups, resulting in a total of ten groups. Five groups conducted the Arabic FCI, and the other five groups conducted the English FCI. The mean percentages of correct scores for each group are presented in Table **4-1**, indicating generally low performance across both languages, with mean scores ranging from 21% to 26%. Notably, a slight language dependence is observed in the pre-test results, favouring the Arabic language, particularly with a mean score of 23.5% for all students in Arabic compared to 23.1% in English. However, this language dependence is negligible when considering the standard error of the mean. Moreover, the difference is statistically insignificant, given that the p-value is larger than 0.05 as calculated using the independent sample T-test. The same result is observed when the means of Engineering and Science students' scores were calculated separately. These outcomes are consistent with findings from similar studies, such as those conducted in Saudi Arabia (Bani-Salameh, 2018), which also noted minimal language dependence within standard error margins. The lack of statistically significant differences among all three groups in Table **4-1** suggests that the observed variations in performance are likely to be random rather than indicating systematic language dependence between student groups.

Course	All		Science		Engineering	
Language	**Arabic**	**English**	**Arabic**	**English**	**Arabic**	**English**
Sample Size	220	257	151	85	69	172
Mean Percentage Score	23.5%	23.1%	22.4%	21.4%	25.9%	23.9%
Standard Error of the Mean	0.8%	0.6%	0.9%	1.1%	1.5%	0.8%
P-value	0.3		0.2		0.1	

Table 4-1 The mean percentages of correct scores for each group

4.2 Comparison of Students' Major

A comparison of FCI performance between science and engineering students, who conducted Arabic or English versions is shown in Table 4-2. On the Arabic version, Engineering students achieved higher scores, with an average percentage of 25.9% compared to 22.4% for science students. The engineering group's scores demonstrated slightly more variability that might be a result of the smaller sample size, as indicated by a standard error of the mean of 1.5%, while the science group's standard error was only 0.9%. Statistical analysis using a T-test revealed a significant difference between the two groups' performance, with a p-value of 0.03.

In the English version, a similar trend was observed, with engineering students achieving a higher mean percentage score of 23.9% compared to 21.4% for science students. The standard error of the mean was 0.8% for engineering students and 1.1% for science students, suggesting a more consistent performance among the engineering group, which may be due to the larger sample size. The difference between the groups in the English version was also statistically significant, with a p-value of 0.005.

These results suggest that engineering students consistently performed better than science students in both language versions of the FCI. The statistical significance of the differences indicates that the observed variations in scores are unlikely to be random, highlighting a potential difference in understanding or preparation between the two groups across both language contexts. This is expected because Engineering students need to score higher in physics in high

school in order to join the College of Engineering as mentioned in the methodology chapter.

Language	**Arabic**		**English**	
Course	Science	Engineering	Science	Engineering
Sample Size	151	69	85	172
Mean Percentage Score	22.4%	25.9%	21.4%	23.9%
Standard Error of the Mean	0.9%	1.5%	1.1%	0.8%
P-value	0.03		0.005	

Table 4-2 FCI scores for science and engineering students who conducted Arabic or English versions.

4.3 Comparison with Gender

Table 4-3 presents the performance of male and female students on the FCI administered in Arabic or English. For the Arabic test, which included 120 male and 100 female participants, the mean percentage score for males was 24.5%, which is slightly higher than the 22.3% mean score for females. Both groups had a standard error of the mean of 1.1%, and the p-value of 0.1 indicates that the difference in performance between genders was not statistically significant. On the other hand, the English FCI, with a larger sample of 199 males and 58 females, indicated a mean percentage score of 23.6% for males and 21.4% for females. The standard error of the mean was lower for males (0.7%) compared to females (1.4%). The p-value of 0.02 indicates a statistically significant difference between male and female scores in the English test, with males performing better. This suggests that while gender differences in performance were not significant in the Arabic test, they were more noticeable in the English test.

Language	Arabic		English	
Gender	**Male**	**Female**	**Male**	**Female**
Sample Size	120	100	199	58
Mean Percentage Score	24.5	22.3	23.6	21.4
Standard Error of the Mean	1.1	1.1	0.7	1.4
P-value	0.1		0.02	

Table 4-3 FCI scores of male and female students, who conducted Arabic or English versions.

4.4 Analysis by FCI Questions

Figure 4-1 presents the percentage of correct responses for each question on the FCI, comparing results from students who took the test in Arabic versus those who took it in English. The analysis combines science and engineering students and shows that while many questions exhibit similar trends across both languages, notable variations exist for specific items. Some questions display a higher correct response rate in Arabic, while others show a better performance in English. This suggests that the language of the question may influence students' understanding and interpretation of certain concepts differently. These variations may indicate that, although overall performance may not differ significantly, individual questions can still reveal disparities in comprehension between the two language versions.

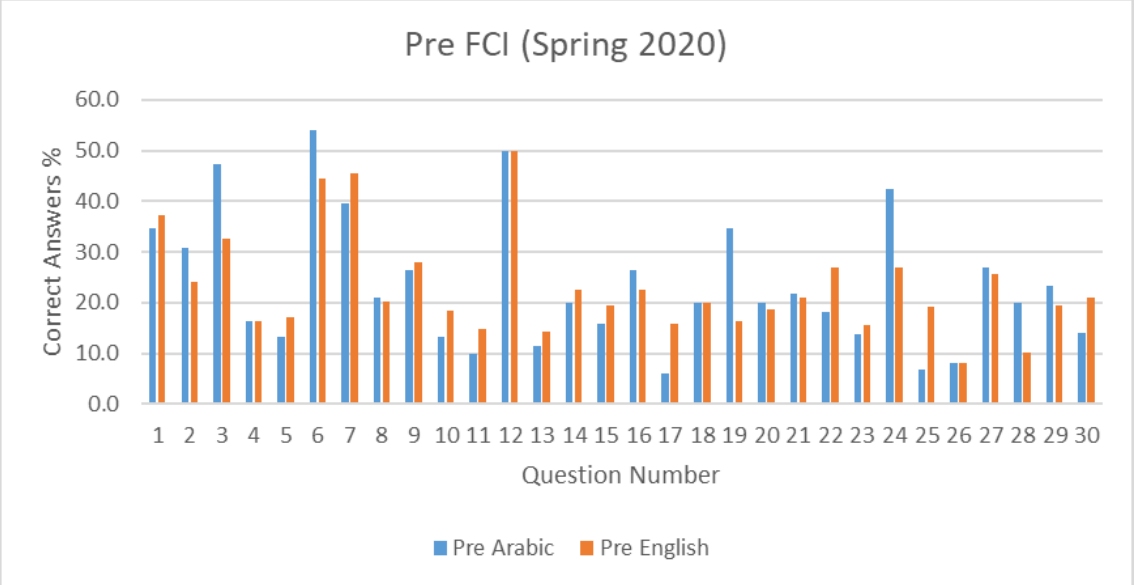


Figure 4-1 The percentage of correct responses for each question on the FCI.

To investigate this trend further, Figure 4-2 illustrates the differences in scores between the Arabic and English versions of the FCI by presenting the percentage difference (Arabic minus English) for each question. Positive values indicate questions where students performed better in Arabic, while negative values indicate better performance in English. The chart shows a varied pattern, with some questions having a notable preference for Arabic and others for English. Specifically, questions 2, 3, 6, 19, 24 and 28 showed the most substantial differences favouring Arabic, while questions 7, 17, 22, 25, and 30 favoured English.

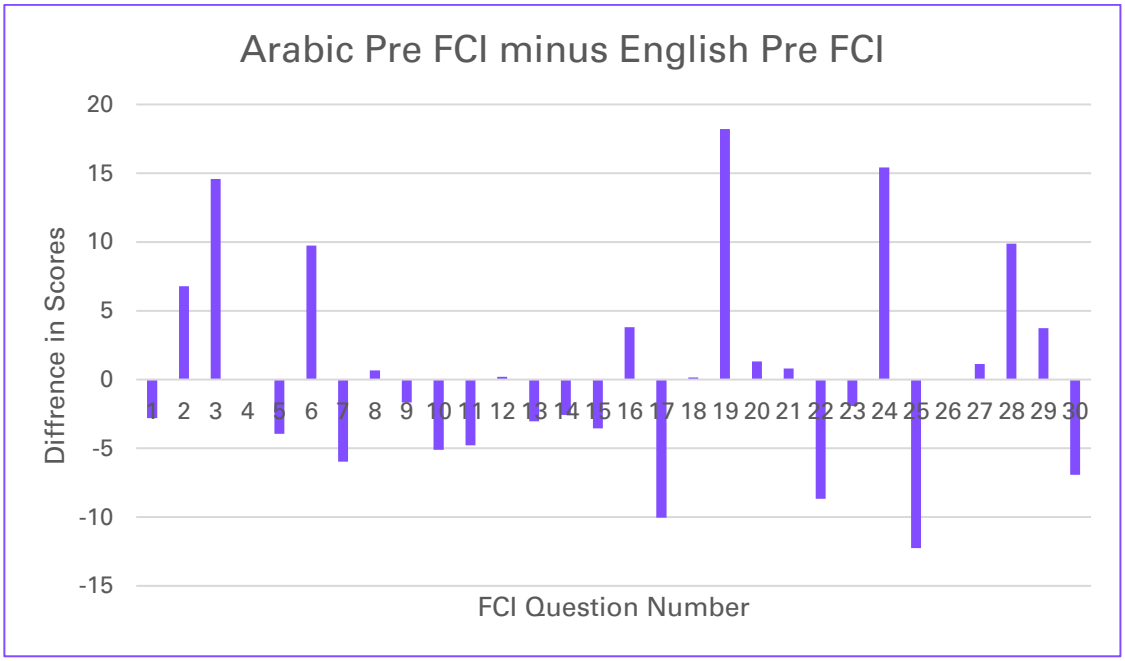


Figure 4-2 The differences in scores between the Arabic and English versions of the FCI

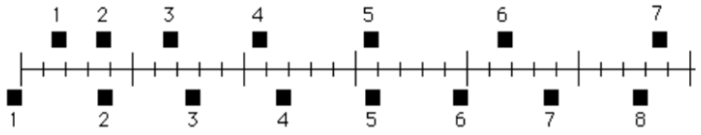
In the following, the questions where there is a noticeable difference between Arabic and English percentages will be discussed. Table 4-4 summarises the questions with the largest differences, where the threshold was set at differences greater than 5% to determine potential significance. Question 19 had the largest positive difference favouring Arabic, while question 25 had the largest negative difference favouring English. The presence of such disparities suggests that while overall performance across the two languages may not be significantly different, certain items on the FCI are more susceptible to language effects. Further analysis is required to assess the language used in each of these questions and how students selected specific answers.

Questions with better performance in Arabic	Questions with better performance in English
2	7
3	17
6	22
19 (largest A)	25 (largest E)
24	30
28	

Table 4-4 The questions with the largest differences in scores

Question 19 on the FCI exhibited the largest performance difference, favouring the Arabic version, as depicted in Table 4-4. Question 19 is presented in Figure **4-3** in Arabic and English. The question involves determining when two moving blocks have the same speed, presented through a series of images that depict the blocks' positions at successive time intervals.

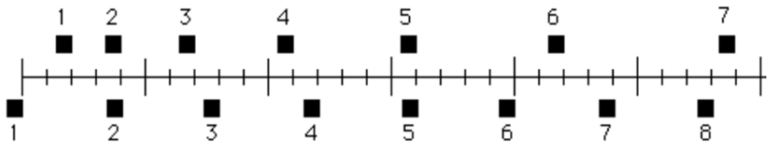
19. مواضع جسمين لفترات من الزمن متتابعة (مقدار كل منها 0.2 ثانية) ممثلة بالأرقام الموضحة في الشكل أدناه. يتحرك الجسمان باتجاه اليمين.



هل بالإمكان أن يأخذ الجسمان نفس السرعة في لحظة من اللحظات؟

a) لا.
b) نعم، عند اللحظة 2.
c) نعم، عند اللحظة 5.
d) نعم، عند اللحظات 2 و 5.
e) نعم، في لحظة من اللحظات خلال الفترة من 3 إلى 4.

19. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



Do the blocks ever have the same speed?

(A) No.
(B) Yes, at instant 2.
(C) Yes, at instant 5.
(D) Yes, at instants 2 and 5.
(E) Yes, at some time during the interval 3 to 4.

Figure 4-3 Question 19 of the FCI in Arabic and English.

The bar charts in Figure **4-4** illustrate the distribution of student responses across the multiple-choice options of question 19 of the Arabic and English FCI. The incorrect choices are shown in purple, and the correct choice is highlighted in orange.

The correct answer, option E, was selected by a larger proportion of students in the Arabic version compared to the English version, which could indicate a better understanding of the language of this question or concept in Arabic.

In both charts, option D was the most frequently selected incorrect answer, indicating a common misconception among students regardless of the language. However, the proportion of students choosing option D was slightly higher in the Arabic version compared to the English version. This suggests that the misconception related to option D might be slightly more prevalent to students when tested in Arabic.

Interestingly, in the English FCI, there is a more even distribution between different options compared to the Arabic version. This distribution suggests that students were somewhat more divided in their misconceptions in English compared to the more focused misunderstanding observed in the Arabic responses.

Overall, the patterns in the distributions suggest that while the misconceptions are similar between the two languages, the focus and spread of incorrect answers vary slightly, potentially reflecting differences in interpretation or understanding related to the language of the assessment.

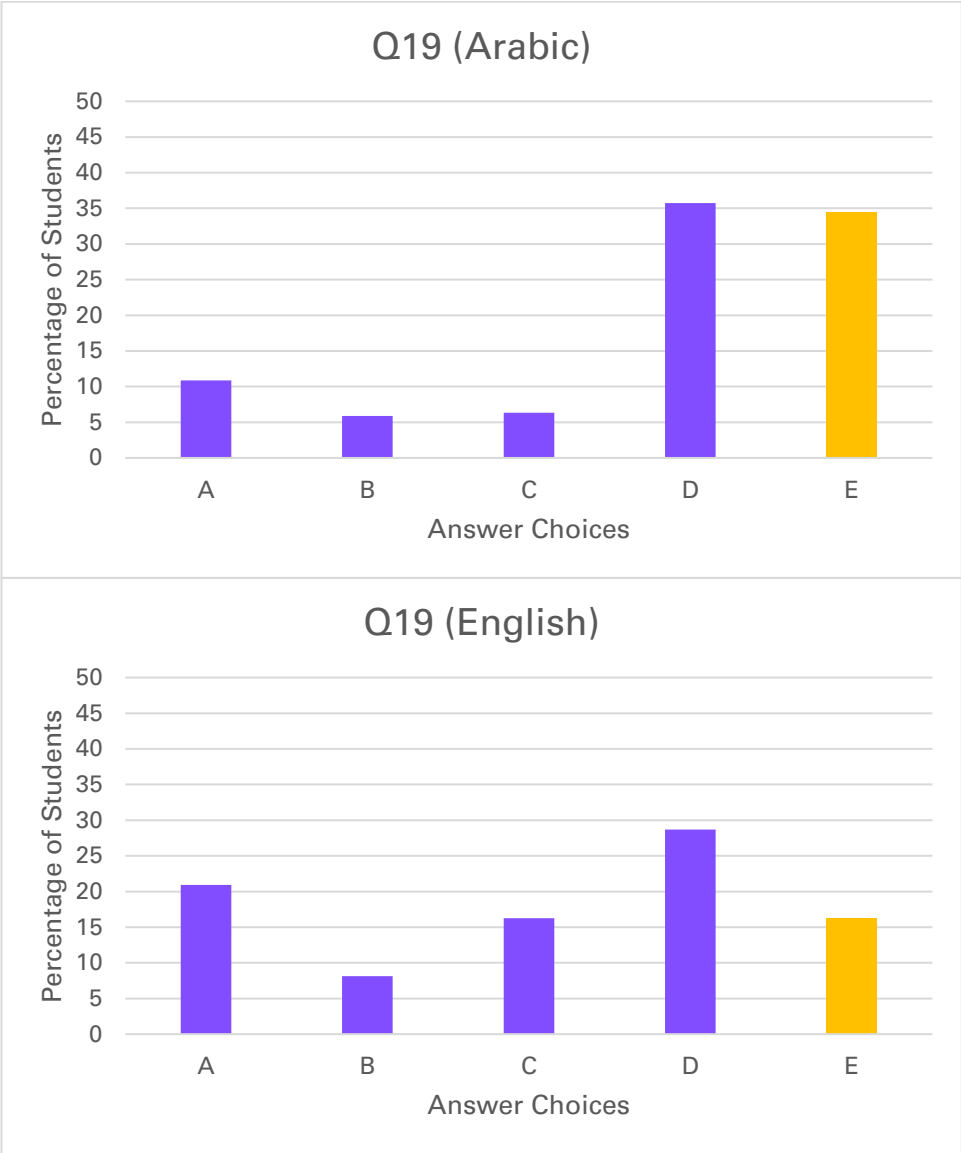


Figure 4-4 **The distribution of student responses across the multiple-choice options of question 19 of the Arabic and English FCI.**

In Contrast, question 25 on the FCI exhibited the largest performance difference, favouring the English version, as depicted in Table **4-4**. In Figure 4-5, the question involves asking about the magnitude of the force applied by a woman on a moving box.

25. امرأة تؤثر بقوة أفقية ثابتة على صندوق كبير. نتيجة لذلك، يتحرك الصندوق أفقياً على الأرض بسرعة ثابتة "v_0".
القوة الأفقية الثابتة التي أثرت بها المرأة:

a) لها نفس مقدار وزن الصندوق.
b) أكبر من وزن الصندوق.
c) لها نفس مقدار القوة الكلية التي تمانع حركة الصندوق.
d) أكبر من القوة الكلية التي تمانع حركة الصندوق.
e) أكبر إما من وزن الصندوق أو من القوة الكلية التي تمانع الحركة.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed "v_o".

The constant horizontal force applied by the woman:

(A) has the same magnitude as the weight of the box.
(B) is greater than the weight of the box.
(C) has the same magnitude as the total force which resists the motion of the box.
(D) is greater than the total force which resists the motion of the box.
(E) is greater than either the weight of the box or the total force which resists its motion.

Figure 4-5 Question 25 of the Arabic and English FCI.

The bar charts in Figure **4-6** illustrate the distribution of student responses across the multiple-choice options of question 25 of the Arabic and English FCI. The incorrect choices are shown in purple and the correct choice in orange.

For the Arabic FCI, the responses indicate a strong tendency towards incorrect options, with option D receiving the highest selections among students. The correct option C was chosen by a relatively small percentage of students, highlighting a prevalent misunderstanding of the force balance required for constant velocity motion.

For the English FCI, the distribution of responses is more spread out compared to the Arabic version. Option B is marginally the more popular option. However, the correct option C is chosen by a larger proportion of students compared to the Arabic FCI.

Overall, the Arabic FCI responses are more concentrated on a few misconceptions, particularly option D, suggesting that students may not fully grasp the concept that a constant horizontal force equal to the opposing forces is required for constant velocity (friction in this case).

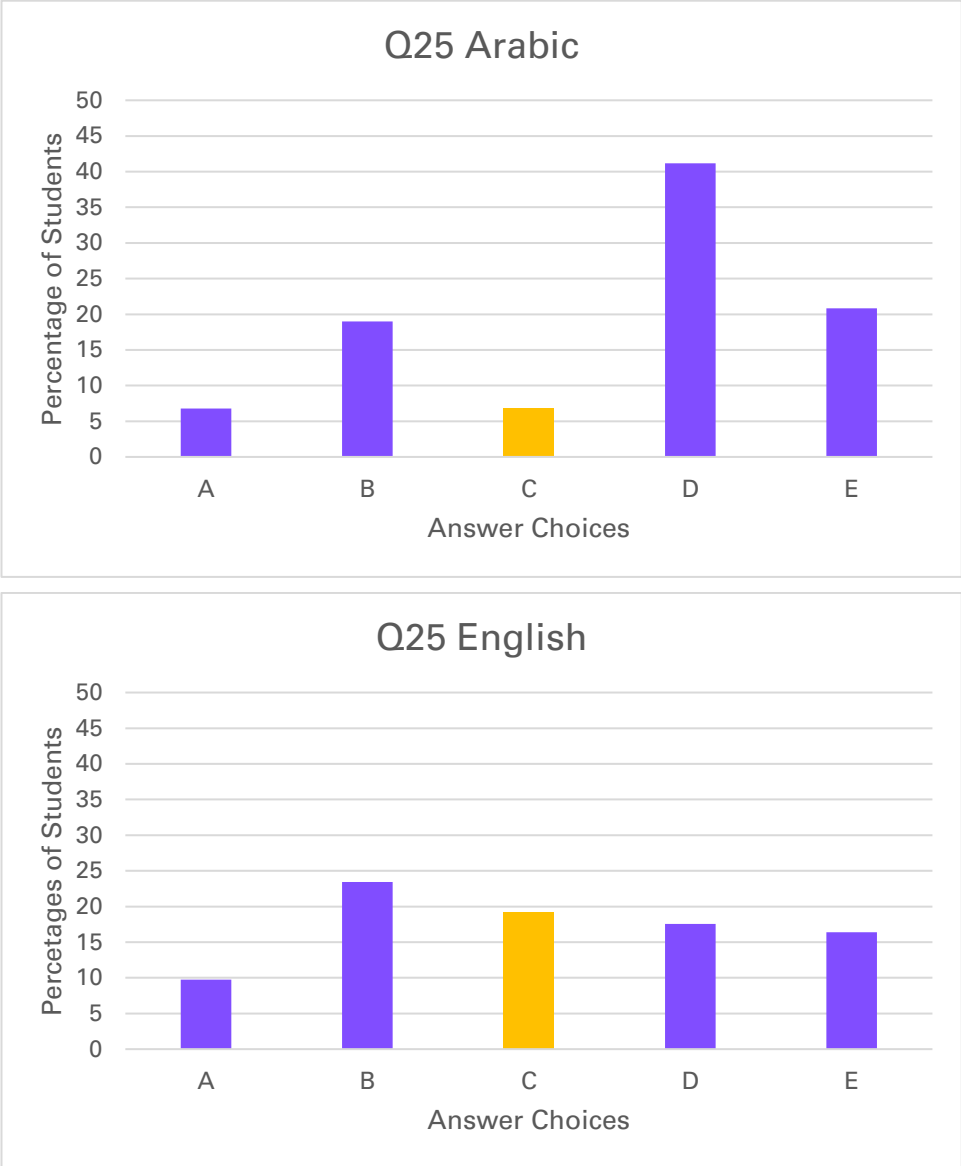


Figure 4-6 **The distribution of student responses across the multiple-choice options of question 25 of the Arabic and English FCI.**

4.5 Dominant Misconceptions

In this section, the dominant misconception will be discussed in detail.

4.5.1 Dominant Misconceptions for the Whole Sample

Table 4-5 provides an overview of the misconceptions for each question of the Arabic and English versions of the FCI following the taxonomy in the methodology chapter. The percentage of the correct answers out of the total responses is highlighted in yellow. Moreover, the percentage of students selecting each

incorrect answer choice, along with the associated misconception codes, are presented. This percentage is calculated after subtracting the number of correct answers. For example, the percentage of correct answers in question 1 is 34.5%. Then 100% - 34.5% (correct choice) = 65.5%(Incorrect choices). The percentages of the incorrect answers in question 1 are calculated out of 65.5%, resulting in incorrect choices percentages adding up to 100%. The misconceptions are categorised according to specific incorrect physics concepts such as "Impetus supplied by 'hit'" (I1), "Only active agents exert forces" (AF1), and "Greater mass implies greater force" (AR1), among others, which were explained in the methodology chapter.

Q No	A	B	C	D	E
1	G3 (46.4)	(9.3)	34.5	(30.7)	(13.6)
2	30.9	G3 (20.7)	(6.4)	G3 (59.3)	(13.6)
3	AF6 (21.6)	AF5, G4 (44.1)	47.3	G2 (9.0)	G1 (25.2)
4	AR1 (87.4)	(3.8)	Ob (1.1)	AR1 (7.7)	16.4
5	Ob (6.6)	13.2	I1, I5, AF2 (37.0)	I1,I5,AF2 (30.9)	I1,I5,AF2,CF(25.4)
6	I5 (80)	54.1	CF (13)	CI2,CF(4)	CF(3)
7	I5(51.9)	39.5	CI2,CF(16.8)	I2,I5,CF(9.9)	CF(21.4)
8	CI3 (56.7)	20.9	I2 (1.2)	I4 (15.2)	I2 (27.5)
9	(6.4)	CI3 (53.8)	K3 (29.5)	(10.3)	26.4
10	13.2	I4 (6.8)	(12.6)	I4 (59.5)	(21.1)
11	Ob,G1 (8.3)	I1,Ob(41.5)	I1 (45.1)	10	G2 (5.2)
12	CI2 (1.9)	50	I3 (72.0)	I3,G5 (15.0)	(11.2)
13	I3 (6.3)	I3,G4,G5(23.3)	I3 (69.3)	11.4	G2 (1.1)
14	K4 (69.0)	K4 (25.9)	CI2 (5.2)	20	I3,G5(0)
15	15.9	AR1(33.7)	AR2(33.1)	AF1 (32.6)	Ob (0)
16	26.4	AR1 (6.5)	AR2(67.7)	AF1 (20)	Ob (5.8)
17	CI1(69.2)	5.9	(3)	CI1,G1(24.4)	AF1 (3.5)
18	AF1,Ob(7.8)	20	I5 (32.9)	I5 (38.3)	CF (21.0)
19	K2 (18.5)	K1 (10)	K1 (10.8)	K1 (60.8)	34.5
20	(27.3)	K2 (6.1)	K2 (46.7)	20	(20)
21	I2 (21.2)	CI3 (26.3)	CI2 (31.4)	I4 (21.2)	21.8
22	AF4 (33.7)	18.2	AF7(9.5)	AF6(45.6)	AF7 (11.2)
23	I2 (16)	13.6	CI3 (33.7)	I2,I3(43.4)	I4 (6.9)
24	42.3	(13)	I3 (57.4)	(7)	I3 (22.6)
25	R2 (7.7)	R2 (21.6)	6.8	R2 (46.9)	CI1 (23.7)
26	AF4(36.2)	R2,R3(32.4)	I4 (5.9)	AF6(25.4)	8.2
27	AF2,R1(56.8)	I3,R1(36.7)	26.8	I1 (4.3)	I4 (2.2)
28	(10.5)	AF1(18.3)	(19)	AR1,AR2(52.3)	20
29	Ob(56.1)	23.2	G1,G2(21.6)	G1(6.1)	AF3(16.2)
30	AF1(3.6)	I1(4.8)	14.1	I1(14.5)	I1 (77.0)

Arabic FCI

Q No	A	B	C	D	E
1	G3(32.1)	22.6	37.4	32.7	12.6
2	24.1	G3(25.4)	28.7	G3(31.5)	14.4
3	AF6(12.5)	AF5,G4(56.5)	32.7	G2(11.9)	G1(19)
4	AR1(61.8)	13.7	Ob(13.7)	AR1(10.8)	16.3
5	Ob(14.7)	17.1	I1,I5,AF2(47.1)	I1,I5,AF2(18.1)	I1,I5,AF2,CF(20.1)
6	I5(69.3)	44.4	CF(7.3)	CI2,CF(17.5)	CF(5.8)
7	I5(50.4)	45.5	CI2,CF(18.5)	I2,I5,CF(15.6)	CF(15.6)
8	CI3(21.9)	20.2	I2(9.1)	I4(28.1)	I2(40.8)
9	13.4	CI3(35.8)	K3(27.9)	22.9	28.0
10	18.3	I4(19.6)	27.9	I4(42.2)	10.3
11	Ob,G1(15.8)	I1,Ob(37.8)	I1(38.8)	14.8	G2(7.2)
12	CI2(11.4)	49.8	I3(60.2)	I3,G5(18.7)	9.8
13	I3(17.9)	I3,G4,G5(29.2)	I3(45.8)	14.4	G2(7.1)
14	K4(57.3)	K4(29.7)	CI2(9.9)	22.6	I3,G5(2.6)
15	19.5	AR1(28.1)	AR2(31.2)	AF1(29.6)	Ob(11.1)
16	22.6	AR1(23.3)	AR2(35.4)	AF1(24.9)	Ob(16.4)
17	CI1(55.1)	16.0	13.8	CI1,G1(24.5)	AF1(6.6)
18	AF1,Ob(8.5)	19.8	I5(27.7)	I5(39.9)	CF(23.9)
19	K2(28.3)	K1(11)	K1(22)	K1(38.7)	16.3
20	31.5	K2(20.4)	K2(38.7)	18.7	9.4
21	I2(24.6)	CI3(28.6)	CI2(28)	I4(18.9)	21.0
22	AF4(19.1)	26.8	AF7(31.2)	AF6(35.7)	AF7(14)
23	I2(23)	15.6	CI3(25.1)	I2,I3(36.4)	I4(15.5)
24	26.8	34.9	I3(32.3)	32.2	I3(19.1)
25	R2(14.5)	R2(34.9)	19.1	R2(26.2)	CI1(24.4)
26	AF4(25.8)	R2,R3(32.3)	I4(20.7)	AF6(21.2)	8.2
27	AF2,R1(31.8)	I3,R1(39)	25.7	I1(19.5)	I4(9.7)
28	16.2	AF1(26.7)	23	AR1,AR2(34)	10.1
29	Ob(32.1)	19.5	G1,G2(24.2)	G1(25.5)	AF3(18.2)
30	AF1(19.5)	I1(25.2)	21.0	I1(21.4)	I1(34)

English FCI

Table 4-5 The misconceptions for each question of the Arabic and English versions of the FCI

To further analyse these misconceptions Table **4-6** consolidates data from Table 4-5 by listing each relevant misconception only once per question. For example, the percentages of the misconception G3 in Question number 2 are added together (20.7% + 59.3% = 80%). Moreover, the dominant misconceptions, with percentages of incorrect answers exceeding 50%, are highlighted in red. In general, the dominant misconceptions are similar in both languages except for some questions, which are shaded in blue. (Note: Although in Q22 there is no dominant misconception with a percentage greater than 50%, we will retain it for

comparison purposes with the Saudi results.) A comprehensive comparison of these differences in dominant misconceptions will be discussed in section 4.6. It is noted that Most questions have the same major misconceptions (in the Arabic and English versions) although they are not always dominant (>50% incorrect responses) in both languages, e.g. Q3, Q9, Q16, Q28. However, some questions (Q8, Q22 and Q29) have different misconceptions in the different languages. It is also noted that some responses in Table 4-5 are not assigned to a misconception, and some are assigned to two or more. Hence, scores can add to less than or greater than 100%.

Q No	Misconception code (percentage)				
1	G3(46.4)				
2	G3(***80***)				
3	G1(25.2)	G2(9.0)	G4(44.1)	AF5(44.1)	AF6(21.6)
4	AR1(***95.1***)	Ob(1.1)			
5	I1(***93.3***)	I5(***93.3***)	AF2(***93.3***)	CF(25.4)	Ob(6.6)
6	I5(***80***)	CF(20)	CI2(4)		
7	I2(9.9)	I5(***61.8***)	CF(***48.1***)	CI2(16.8)	
8	I2(28.7)	I4(15.2)	CI3(***56.7***)		
9	CI3(***53.8***)	K3(29.5)			
10	I4(***66.3***)				
11	G1(8.3)	G2(5.2)	I1(***86.6***)	Ob(49.8)	
12	CI2(1.9)	I3(***87***)	G5(15.0)		
13	I3(***98.9***)	G2(1.1)	G4(23.3)	G5(23.3)	
14	CI2(5.2)	I3(0)	K4(***94.9***)	G5(0)	
15	AF1(32.6)	Ob(0)	AR1(33.7)	AR2(33.1)	
16	AF1(20)	Ob(5.8)	AR1(6.5)	AR2(***67.7***)	
17	AF1(3.5)	CI1(***93.6***)	G1(24.4)		
18	AF1(7.8)	CF(21.0)	I5(***71.2***)	Ob(7.8)	
19	K1(***81.6***)	K2(18.5)			
20	K2(***52.8***)				
21	CI2(31.4)	CI3(26.3)	I2(21.2)	I4(21.2)	
22	AF4(33.7)	AF6(45.6)	AF7(20.7)		
23	CI3(33.7)	I2(***59.4***)	I3(43.4)	I4(6.9)	
24	I3(***80***)				
25	CI1(23.7)	R2(***76.2***)			
26	AF4(36.2)	AF6(25.4)	I4(5.9)	R2(32.4)	R3(32.4)
27	AF2(***56.8***)	I1(4.3)	I3(36.7)	I4(2.2)	R1(***93.5***)
28	AF1(18.3)	AR1(***52.3***)	AR2(***52.3***)		
29	AF3(16.2)	G1(27.7)	G2(21.6)	Ob(***56.1***)	
30	AF1(3.6)	I1(***96.3***)			

This table shows misconceptions in each question (Arabic FCI)

Q No	Misconception code (percentage)				
1	G3(32.1)				
2	G3(***56.9***)				
3	G1(19)	G2(11.9)	G4(***56.5***)	AF5(***56.5***)	AF6(12.5)
4	AR1(***72.6***)	Ob(13.7)			
5	I1(***85.3***)	I5(***85.3***)	AF2(***85.3***)	CF(20.1)	Ob(14.7)
6	I5(***69.3***)	CF(30.6)	CI2(17.5)		
7	I2(15.6)	I5(***66***)	CF(***49.7***)	CI2(18.5)	
8	I2(***49.9***)	I4(28.1)	CI3(21.9)		
9	CI3(35.8)	K3(27.9)			
10	I4(***61.8***)				
11	G1(15.8)	G2(7.2)	I1(***76.6***)	Ob(***53.6***)	
12	CI2(11.4)	I3(***78.9***)	G5(18.7)		
13	I3(***92.9***)	G2(7.1)	G4(29.2)	G5(29.2)	
14	CI2(9.9)	I3(2.6)	K4(***87***)	G5(2.6)	
15	AF1(29.6)	Ob(11.1)	AR1(28.1)	AR2(31.2)	
16	AF1(24.9)	Ob(16.4)	AR1(23.3)	AR2(35.4)	
17	AF1(6.6)	CI1(***79.6***)	G1(24.5)		
18	AF1(8.5)	CF(23.9)	I5(***67.6***)	Ob(8.5)	
19	K1(***71.7***)	K2(28.3)			
20	K2(***59.1***)				
21	CI2(28)	CI3(28.6)	I2(24.6)	I4(18.9)	
22	AF4(19.1)	AF6(35.7)	AF7(45.2)		
23	CI3(25.1)	I2(***59.4***)	I3(36.4)	I4(15.5)	
24	I3(***51.4***)				
25	CI1(24.4)	R2(***75.6***)			
26	AF4(25.8)	AF6(21.2)	I4(20.7)	R2(32.3)	R3(32.3)
27	AF2(31.8)	I1(19.5)	I3(39)	I4(9.7)	R1(***70.8***)
28	AF1(26.7)	AR1(34)	AR2(34)		
29	AF3(18.2)	G1(***49.7***)	G2(24.2)	Ob(32.1)	
30	AF1(19.5)	I1(***80.6***)			

This table shows misconceptions in each question (English FCI

Table 4-6 Percentage of incorrect responses to each question, combined according to different misconceptions.

4.5.2 Dominant Misconceptions for Engineering and Science Students

The dominant misconceptions in physics for science major students are presented in Table 4-7. Each table lists the misconceptions associated with each question, highlighting the specific dominant misconceptions that are most prevalent in the Arabic and English versions of the FCI.

There is some overlap in misconceptions between the Arabic and English versions but also notable differences. For example, in Question 8, students consistently display the CI3 misconception (the last force to act determines

motion) in the Arabic FCI, whereas the English FCI shows a shift towards the I2 misconception (impetus dissipation).

Table 4-7 highlights the differences in some dominant misconceptions between the two languages could be influenced by the phrasing of questions, familiarity with terminology, or the instructional language used in high school. For instance, questions 8 and 9 reveal a high prevalence of misconception CI3 in the Arabic FCI, indicating a persistent misunderstanding about the relationship between mass and force. However, in the English FCI, this misconception is less dominant, which might indicate a clearer understanding when the concept is framed in English or could reflect difficulties in language comprehension rather than conceptual understanding.

Q No	Misconception code (percentage)				
1	G3(47.6)				
2	**G3(79.4)**				
3	G1(27.9)	G2(9.3)	G4(41.9)	AF5(41.9)	AF6(20.9)
4	**AR1(94.3)**	Ob(1.6)			
5	**I1(95.1)**	**I5(95.1)**	**AF2(95.1)**	CF(25)	Ob(4.8)
6	**I5(82.2)**	CF(17.8)	CI2(5.5)		
7	I2(11.0)	**I5(61.5)**	**CF(49.5)**	CI2(16.5)	
8	I2(30.1)	I4(15.4)	**CI3(54.5)**		
9	**CI3(50.5)**	K3(30.8)			
10	I4(**65.4**)				
11	G1(6.1)	G2(3.8)	**I1(90)**	Ob(48.8)	
12	CI2(2.5)	**I3(83.8)**	G5(13.8)		
13	**I3(92.6)**	G2(1.5)	G4(25.4)	G5(25.4)	
14	CI2(5.6)	I3(0)	**K4(94.5)**	G5(0)	
15	AF1(41.4)	Ob(0)	AR1(31.0)	AR2(27.6)	
16	AF1(25.7)	Ob(5.7)	AR1(5.7)	**AR2(62.9)**	
17	AF1(2.2)	**CI1(93.4)**	G1(22.8)		
18	AF1(10)	CF(23.3)	**I5(66.7)**	Ob(10)	
19	**K1(79.3)**	K2(20.7)			
20	K2(46.9)				
21	CI2(30.1)	CI3(30.1)	I2(23.9)	I4(16.0)	
22	AF4(32.5)	AF6(43.9)	AF7(23.6)		
23	CI3(34.4)	**I2(61.6)**	I3(43.2)	I4(4)	
24	**I3(81.8)**				
25	CI1(25.9)	**R2(74.1)**			
26	AF4(34.4)	AF6(21.9)	I4(5.5)	R2(38.3)	R3(38.3)
27	**AF2(63.2)**	I1(3.2)	I3(32.6)	I4(1.1)	R1(**95.8**)
28	AF1(20.2)	**AR1(51.0)**	**AR2(51.0)**		
29	AF3(16.2)	G1(28.6)	G2(5.7)	**Ob(55.2)**	
30	AF1(5.1)	**I1(94.9)**			
Misconceptions in each question (Science, Arabic FCI)					

Q No	Misconception code (percentage)				
1	G3(27.1)				
2	**G3(53.5)**				
3	G1(26.2)	G2(9.8)	**G4(50.8)**	**AF5(50.8)**	AF6(13.1)
4	**AR1(60.6)**	Ob(18.2)			
5	**I1(90)**	**I5(90)**	**AF2(90)**	CF(24.3)	Ob(10)
6	**I5(72.3)**	CF(27.7)	CI2(2.1)		
7	I2(24.5)	**I5(71.5)**	**CF(53.1)**	CI2(8.2)	
8	I2(43.6)	I4(27.0)	CI3(29.0)		
9	CI3(35.1)	K3(36.8)			
10	**I4(52.7)**				
11	G1(14.1)	G2(12.7)	**I1(73.2)**	Ob(47.9)	
12	CI2(13.9)	**I3(77.8)**	G5(22.2)		
13	**I3(94.3)**	G2(5.7)	G4(25.7)	G5(22.2)	
14	CI2(8.3)	I3(1.4)	**K4(90.3)**	G5(1.4)	
15	AF1(21.4)	Ob(21.4)	AR1(31.4)	AR2(25.7)	
16	AF1(25.8)	Ob(25.8)	AR1(16.1)	AR2(32.3)	
17	AF1(6.06)	**CI1(77.2)**	G1(22.7)		
18	AF1(3.2)	CF(25.8)	**I5(71)**	Ob(3.2)	
19	**K1(74.5)**	K2(25.4)			
20	**K2(54.9)**				
21	CI2(37.9)	CI3(31.0)	I2(25.9)	I4(5.2)	
22	AF4(25.5)	AF6(33.3)	AF7(41.2)		
23	CI3(28.3)	**I2(51.7)**	I3(26.7)	I4(20)	
24	**I3(53.3)**				
25	CI1(22.0)	**R2(78)**			
26	AF4(27.8)	AF6(14.8)	I4(25.9)	R2(31.5)	R3(31.5)
27	AF2(32.1)	I1(20.8)	I3(35.8)	I4(11.3)	**R1(67.9)**
28	AF1(28.3)	AR1(34.0)	AR2(34.0)		
29	AF3(24)	G1(38)	G2(24)	Ob(38)	
30	AF1(16.7)	**I1(77.4)**			
Misconceptions in each question (science, English)					

Table 4-7 The misconceptions identified in each question for Arabic and English versions of the FCI taken by the Science major students.

Table **4-8** presents the misconceptions identified in each question for both the Arabic and English versions of the FCI administered to Engineering major students. The data reveals that certain misconceptions are prevalent across both languages, while others are language-specific.

In both versions of the FCI, misconceptions such as I1 (impetus supplied by 'hit'), I3 (impetus dissipation), and AR1 (greater mass implies greater force) are frequently observed, suggesting persistent misunderstandings about fundamental physics concepts related to force and motion. These misconceptions reflect a reliance on pre-Newtonian ideas of impetus, implying that students believe an object in motion requires a continuous force to maintain its motion. This misconception is deeply rooted and possibly influenced by their previous physics education in Arabic.

Another interesting feature is that some misconceptions were not picked by any students in the Arabic version, such as Ob (Obstacles exert no force) in questions 4 and 15, G5 in questions 13 and 14, G2 in question 13 and I3 in question 14. These misconceptions are shaded in orange in Table 4-7 and Table **4-8**. On the other hand, some students picked these misconceptions in the English version. Nevertheless, this misconception Ob was dominant in question 29 in the Arabic version but not in the English version.

Q No	Misconception code (percentage)				
1	G3(43.2)				
2	**G3(80.9)**				
3	G1(16)	G2(8)	**G4(52)**	**AF5(52)**	AF6(24)
4	AR1(**96.6**)	Ob(0)			
5	**I1(89.5)**	**I5(89.5)**	**AF2(89.5)**	CF(26.3)	Ob(10.5)
6	**I5(74.1)**	CF(25.9)	CI2(0)		
7	I2(7.5)	**I5(62.5)**	CF(45)	CI2(17.5)	
8	I2(24.5)	I4(14.3)	**CI3(61.2)**		
9	**CI3(61.2)**	K3(26.5)			
10	**I4(68.4)**				
11	G1(12.9)	G2(8.1)	**I1(79)**	**Ob(51.6)**	
12	CI2(0)	**I3(96.3)**	G5(18.5)		
13	**I3(100)**	G2(0)	G4(18.2)	G5(0)	
14	CI2(4.2)	I3(0)	**K4(95.8)**	G5(0)	
15	AF1(15.6)	Ob(0)	AR1(39.7)	AR2(44.9)	
16	AF1(8)	Ob(6)	AR1(8)	**AR2(78)**	
17	AF1(6.2)	**CI1(93.9)**	G1(27.7)		
18	AF1(2.1)	CF(14.9)	**I5(83)**	Ob(2.1)	
19	**K1(86)**	K2(14.0)			
20	**K2(65.4)**				
21	CI2(31.3)	CI3(14.6)	I2(12.5)	I4(41.7)	
22	AF4(37.0)	**AF6(50)**	AF7(2.2)		
23	CI3(32)	**I2(54)**	I3(44)	I4(14)	
24	**I3(75.8)**				
25	CI1(18.6)	**R2(81.3)**			
26	AF4(40.4)	AF6(33.3)	I4(7.0)	R2(19.3)	R3(19.3)
27	AF2(43.2)	I1(6.8)	I3(45.5)	I4(4.5)	**R1(88.7)**
28	AF1(14.3)	**AR1(55.1)**	**AR2(55.1)**		
29	AF3(16.3)	G1(25.6)	G2(7.0)	**Ob(58.1)**	
30	AF1(0)	**I1(100)**			

Misconceptions in each question (Engineering, Arabic)

Q No	Misconception code (percentage)				
1	G3(35)				
2	**G3(58.6)**				
3	G1(15.0)	G2(13.1)	**G4(59.8)**	**AF5(59.8)**	AF6(12.1)
4	**AR1(78.3)**	Ob(11.6)			
5	**I1(83.3)**	**I5(83.5)**	**AF2(83.5)**	CF(18.2)	Ob(16.7)
6	**I5(67.8)**	CF(32.3)	CI2(10)		
7	I2(10.5)	**I5(62.8)**	CF(47.7)	CI2(24.4)	
8	**I2(53)**	I4(28.4)	CI3(18.7)		
9	CI3(36.1)	K3(23.8)			
10	**I4(66.7)**				
11	G1(16.8)	G2(4.4)	**I1(78.8)**	**Ob(56.9)**	
12	CI2(10.3)	**I3(79.3)**	G5(17.2)		
13	**I3(92.3)**	G2(7.7)	G4(31.0)	G5(31.0)	
14	CI2(11.0)	I3(3.4)	**K4(85.8)**	G5(3.4)	
15	AF1(34.1)	Ob(5.4)	AR1(26.4)	AR2(34.1)	
16	AF1(24.4)	Ob(11.8)	AR1(26.8)	AR2(37)	
17	AF1(6.9)	**CI1(80.8)**	G1(25.4)		
18	AF1(11.2)	CF(23.2)	**I5(56.6)**	Ob(11.2)	
19	**K1(70.3)**	K2(29.7)			
20	**K2(61.3)**				
21	CI2(23)	CI3(27.4)	I2(23.9)	I4(25.6)	
22	AF4(16.0)	AF6(36.8)	**AF7(48)**		
23	CI3(23.6)	**I2(62.9)**	I3(40.9)	I4(13.4)	
24	**I3(50.5)**				
25	CI1(25.1)	**R2(74.3)**			
26	AF4(25)	AF6(23.6)	I4(18.8)	R2(32.6)	R3(32.6)
27	AF2(31.7)	I1(18.8)	I3(40.6)	I4(8.9)	**R1(72.3)**
28	AF1(26.1)	AR1(34.1)	AR2(34.1)		
29	AF3(15.7)	**G1(54.7)**	G2(24.3)	Ob(29.6)	
30	AF1(20.7)	**I1(79.2)**			

Misconceptions in each question (Engineering, English)

Table 4-8 **The misconceptions identified in each question for Arabic and English versions of the FCI taken by the Engineering major students.**

4.6 Differences in Dominant Misconceptions

In this section, we will focus on the differences in dominant misconceptions between the Arabic and English versions of the FCI. Table 4-9 summarizes the dominant misconceptions in physics among students who learned physics in Arabic in high school and were tested using the FCI in both Arabic and English before receiving any university-level physics instruction. The table compares the percentage of correct answers and the dominant misconceptions across both versions of the FCI, highlighting the overall results for the entire sample, as well as for science and engineering students separately.

The results show that for Question 8, a common misconception in the Arabic FCI (both overall and separately for science and engineering students) is CI3, which refers to the belief that the last force to act determines the motion. In contrast, the English FCI reveals a shift to the I2 misconception (the idea that an object in motion retains an "impetus" unless acted upon), with no dominant misconception identified among science students.

For Question 9, the CI3 misconception persists across all Arabic FCI groups, while no dominant misconception emerges in the English FCI across all groups, indicating a potential language issue-related difficulty in overcoming this misconception or understanding the language of the question.

Question 16 highlights the AR2 misconception (most active agent produces the greatest force) in the Arabic FCI across all groups. However, no equivalent misconception is dominant in the English FCI, suggesting that the concept might not be clearly understood in English or that the question in English could not help in revealing the same misunderstanding.

In Question 22, a shift occurs where the misconception AF6 (force causes acceleration to terminal velocity) is dominant in the Arabic FCI for all groups except for science students, whereas AF7 (related to active force wear) becomes dominant for the English FCI among all but science students. This suggests that students interpreted the questions in Arabic and English differently.

For Question 27, the misconception AF2, R1 (active force wears out) and (mass makes things stop) consistently appeared in both Arabic and English FCI across all groups. However, the misconception AF2 disappeared in the English version. Again, this might be due to the misunderstanding of the language of the question.

Question 28 revealed misconceptions AR1 and AR2 (greater mass implies greater force" and "most active agent produces the greatest force) as dominant across all Arabic groups, whereas no clear misconception was prevalent in the English FCI.

Finally, in Question 29, the misconception Ob (obstacles exert no force) is dominant across all Arabic FCI groups, whereas the G1 misconception (air pressure-assisted gravity) is more common in the English FCI. This difference might reflect variances in how concepts are linguistically framed or taught in the two languages or just indicate a misunderstanding of the language of the question.

In general, the Arabic dominant misconceptions aligned best with the dominant misconceptions in the Saudi paper, while the English ones differed significantly (Bani-Salameh, 2017).

Question No	Arabic % Correct	English % Correct	Arabic FCI (All)	Arabic FCI (Science)	Arabic FCI (Engineering)	English FCI (All)	English FCI (Science)	English FCI (Engineering)
8	20.9	20.2	CI3	CI3	CI3	I2	NDM	I2
9	26.4	28.0	CI3	CI3	CI3	NDM	NDM	NDM
16	26.4	22.6	AR2	AR2	AR2	NDM	NDM	NDM
22	18.2	26.8	AF6	NDM	AF6	AF7	NDM	AF7
27	26.8	25.7	AF2, R1	AF2, R1	AF2, R1	R1	R1	R1
28	20.0	10.1	AR1, AR2	AR1, AR2	AR1, AR2	NDM	NDM	NDM
29	23.2	19.5	Ob	Ob	Ob	G1	G1	G1

Table 4-9 Comparison of the dominant misconceptions across the English and Arabic FCI for the entire sample, as well as for science and engineering students separately (NDM stands for No Dominant Misconceptions).

Overall, Table 4-9 illustrates how language can influence the dominance of specific misconceptions, with some misconceptions being more dominant in one language than the other, possibly due to differences in linguistic framing or prior instructional experiences in high school. The findings underscore the importance of addressing language-specific challenges in physics education to better support student understanding across different linguistic contexts.

4.7 Chapter Summary

This chapter investigated how cultural and linguistic factors might influence students' understanding of physics, specifically through the analysis of pre-FCI assessments conducted in Arabic and English. The chapter detailed the performance of students in Physics 1 courses across engineering and science

majors, highlighting overall low FCI scores ranging from 21% to 26%, with a slight advantage for Arabic scores (23.5%) over English scores (23.1%). However, these differences were statistically insignificant.

The analysis includes comparisons of performance based on course major and gender. Engineering students outperformed science students in both language versions of the FCI, with statistically significant differences (p-values of 0.03 for Arabic and 0.005 for English). Gender differences were not significant in the Arabic test but were notable in the English version, where males scored higher (p-value of 0.02).

This chapter also provided analysis of individual FCI questions, revealing that language can impact students' comprehension differently. Some questions favoured Arabic responses, while others favoured English, indicating that specific items may be more susceptible to language effects.

Dominant misconceptions were identified, with many being consistent across both languages. However, some misconceptions varied, suggesting that language comprehension and phrasing influenced students' understanding. The findings emphasised the need to address language-specific challenges in physics education to enhance student comprehension across different linguistic contexts.

Chapter 5
Effect of Teaching Methods

The aim of this chapter is to answer Research Question 2: How does the teaching method affect students' learning gain and attitude toward physics? In order to do so, the findings derived from comparing the outcomes of traditional teaching versus peer instruction are presented. This comparison includes the results of pre- and post-Half FCI assessments administered in either Arabic or English in SPRING 2021 as well as think-aloud interviews and data from CLASS surveys. A summary of the data collected for this study is presented in Table 5-1.

Semester	**Spring 2021 (Online)**	
Teaching Method	PI	Traditional
Major	Science	Engineering
Online Arabic Half FCI	13 (M:7 , F:6)	40 (M:31 , F:9)
Online English Half FCI	13 (M:6 , F:7)	21 (M:13 , F:8)
Think aloud interviews	4	7
Online CLASS	15 (M:7 , F:8)	21 (M:14 , F:7)

Table 5-1 A summary of the data collected in SPRING 2021

5.1 Comparison of Pre- and Post- Half FCI Assessments:

This study was conducted in Spring 2021 during the COVID-19 pandemic when all teaching was conducted online. Physics for Science instructors incorporated some PI components in their teaching. The instructors decided to utilise the breakout rooms feature in Google Meet and the voting feature in Moodle to facilitate PI discussion during online class time. On the other hand, physics for Engineering students was taught traditionally without any PI components. One class from each course was chosen, and both classes were taught by a young Omani instructor. Each class is further divided into two groups in the tutorial session. This division comes normally and randomly by students' registration, and the researcher did not have any control over that. One subgroup did the Arabic Half FCI, and the other subgroup did the English Half FCI. Another aspect that was out of the control of the researcher is that traditional teaching students were engineering students, and PI students were science students, resulting in an inability to separate the effect of the teaching method from the student's major.

Chapter 4 revealed that there was some major dependence. An online Half FCI was run to the four groups (two are the traditional teaching, and the other two are the PI groups) using Moodle, to maintain the security of the test. Two groups took the Arabic version of the Half FCI (one is the traditional teaching, and the other is the PI group), and the other two groups did the English version (one is the traditional teaching, and the other is the PI group).

The test response rates for the traditional and peer instruction groups were 27.3% and 23.0 % respectively. The response rate was initially more but some student results were disqualified because of many missing answers. Moreover, only matched sample results were used to compare individual students' results both before and after instructions.

5.1.1 Comparing Traditional vs. Peer Instruction Methods

Table 5-2 summarises the pre-test and post-test results for students who underwent either traditional instruction or Peer Instruction (PI), irrespective of whether the Half FCI was administered in Arabic or English. In general, both groups got low gain range as indicated in Table 3-4.

The mean pre-test score for engineering students receiving traditional instruction was (24.8±1.8)%, which improved to (35.2±2.5)% in the post-test. This corresponded to a normalised gain of (0.13±0.04), which was calculated using equation 1.

For science students receiving PI, the pre-test mean score was slightly higher at 25.8± 2.8)%, with a post-test score of (33.0 ± 4.3)%. This resulted in a normalised gain of (0.11 ± 0.05). It is clear that both groups have enhanced their learning, as the pre and post-test scores differ by more than the standard error. However, there is no significant difference in the learning gains of the different groups (PI and Traditional), with a Mann-Whitney test giving a p-value of 0.42.

	All Traditional (Engineering)		**All PI (Science)**	
	Pre-test	Post-test	Pre-test	Post-test
Number of Participants	61		26	
Mean percentage score (%)	24.8	35.2	25.8	33.0
Standard error of the mean (%)	1.8	2.5	2.8	4.3
Normalised Gain	0.13±0.04		0.11±0.05	
P-Value (Mann's Whittney Test)	0.42			

Table 5-2 The pre-and post-Half FCI results for students who underwent either traditional instruction or Peer Instruction (PI)

5.1.2 Comparing Arabic vs. English Languages

This section examines how language (Arabic versus English) impacts students' performance, regardless of the different teaching methods employed. Table 5-3 presents the pre-test and post-test results of students who took the Arabic and English Half FCI, regardless of teaching method. In general, both groups got a low gain range, as indicated in Table 3-4.

For the group using Arabic, the mean pre-test score was (26.4±1.8)%, which increased to (32.9±2.4)% after the post-test, yielding a normalised gain of (0.08±0.03).

In contrast, the group using English had a lower mean pre-test score of (23.1±2.6)%, which improved to (37.2±4.2)% in the post-test, with a higher normalised gain of (0.18±0.06). It is interesting to note that for students taking the test in English, their pre-score is lower than that of those taking an Arabic test. This is likely due to them being less familiar with reading English or knowing the physics terms in English. However, after a semester of studying physics in English, their post-test scores are higher than those of students taking the test in Arabic. These differences are not quite outside the margin of error but hint at the increasing confidence in using English to study physics. The calculated learning gain for the different language groups differs by more than the standard error, although a Mann-Whitney test does not reveal significance at the 5% level.

	All Arabic		**All English**	
	Pre-test	Post-test	Pre-test	Post-test
Number of Participants	53		34	
Mean percentage score (%)	26.4	32.9	23.1	37.2
Standard error of the mean (%)	1.8	2.4	2.6	4.2
Normalised Gain	0.08±0.03		0.18±0.06	
P-Value (Mann-Whittney Test)	0.12			

Table 5-3 The pre-test and post-test results of students who took the Arabic and English Half FCI

5.1.3 Arabic vs. English Comparison by Teaching Method (Traditional vs PI)

The effect of test language split by teaching method is presented in **Table 5-4**. In general, both groups got a low gain range as indicated in Table 3-4.

For the Traditional Instruction, the students in the Arabic group started with a pre-test score of 26.4% and improved to 33.4% after instruction. The normalised gain was (0.08 ± 0.03). For the English group, the pre-test score was lower at 21.8%, but their post-test score increased significantly to 38.8%. This yielded a higher normalised gain of (0.22 ± 0.08) for students taking the test in English. Although this gain is larger than the Arabic group, the p-value of 0.25 shows that the difference in normalised gains between the two groups is not statistically significant.

For the Peer Instruction (PI), the Arabic group had a pre-test score of 26.4% and a post-test score of 31.3%, resulting in a normalised gain of (0.07 ± 0.07). In contrast, students in the English PI group showed greater improvement, with a pre-test score of 25.3% and a post-test score of 34.6%. The normalised gain was (0.13 ± 0.08).

Regarding the impact of the instructional method for both language groups, the traditional method showed slightly higher gains compared to the PI method, particularly in the English group, where traditional instruction resulted in a higher normalised gain (0.22±0.08) compared to PI (0.13±0.08).

In general, while all groups showed improvement from pre-test to post-test, the English language groups demonstrated higher gains overall, especially under traditional instruction. However, none of the differences were statistically significant based on the p-values presented (0.15 and 0.25).

	All Traditional		**All PI**	
	Arabic	English	Arabic	English
Number of Participants	40	21	13	13
Mean percentage score (%)	Pre=26.4 Post=33.4	Pre=21.8 Post=38.8	Pre=26.4 Post=31.3	Pre=25.3 Post=34.6
Standard error of the mean (%)	Pre=2.1 Post=2.6	Pre=3.3 Post=5.6	Pre=3.4 Post=6.0	Pre=4.5 Post=6.3
Normalised Gain	0.08±0.03	0.22±0.08	0.07±0.07	0.13±0.08
P-Value	0.15		0.25	

Table 5-4 The results of Half FCI based on the test language and teaching method.

5.1.4 Comparing Male and Female Students

A summary of the pre-test and post-test results for male and female students who completed the Half FCI, regardless of whether the test was conducted in Arabic or English, and regardless of teaching method, is presented in Table 5-5.

The mean pre-test score for male students was 25.2%, which increased to 33.5% in the post-test. This resulted in a normalised gain of (0.10±0.03).

On the other hand, female students had a lower mean pre-test score of 25.0%, but their post-test score showed a greater improvement, increasing to 36.7%. The normalised gain for females was (0.15±0.06), higher than that of males, but the p-value considering the normalized gains for male and female students remained above the 0.05 threshold, indicating that there is no statistically significant difference between the performance of the two groups.

	All Male Students		**All Female Students**	
	Pre-test	Post-test	Pre-test	Post-test
Number of Participants	M=57		F=30	
Mean percentage score (%)	25.2	33.5	25.0	36.7
Standard error of the mean (%)	1.7	2.6	3.0	4.0
Normalised Gain	0.10±0.03		0.15±0.06	
P-Value (Mann-Whittney Test)	0.41			

Table 5-5 The Half FCI results for male and female students.

5.1.5 Effect of Language by Question

Unlike the full-length FCI, the pre-and post-Half FCI have different questions except for three questions, as mentioned in Table 3-1. This limited conducting a complete comparison of questions as has been done in Chapter 4. Nevertheless, a comparison of the results of the three identical questions, namely questions 2, 26 and 28 of the pre-and post-tests for all groups and both versions, was conducted and is presented in Figure 5-1. In the English version, there was an increase in the percentage of correct answers for the three questions in the case of traditional instruction. However, there was an improvement in two questions only in peer instruction, with no improvement in Q2. In the Arabic version, the traditional group improved in all questions, but the PI group improved in two questions only, and there was reduced performance for Q26. There was a big improvement in Q28 in both languages and both teaching methods. In Q26, there

was improvement in English, but less improvement or even reduced performance in Arabic PI.

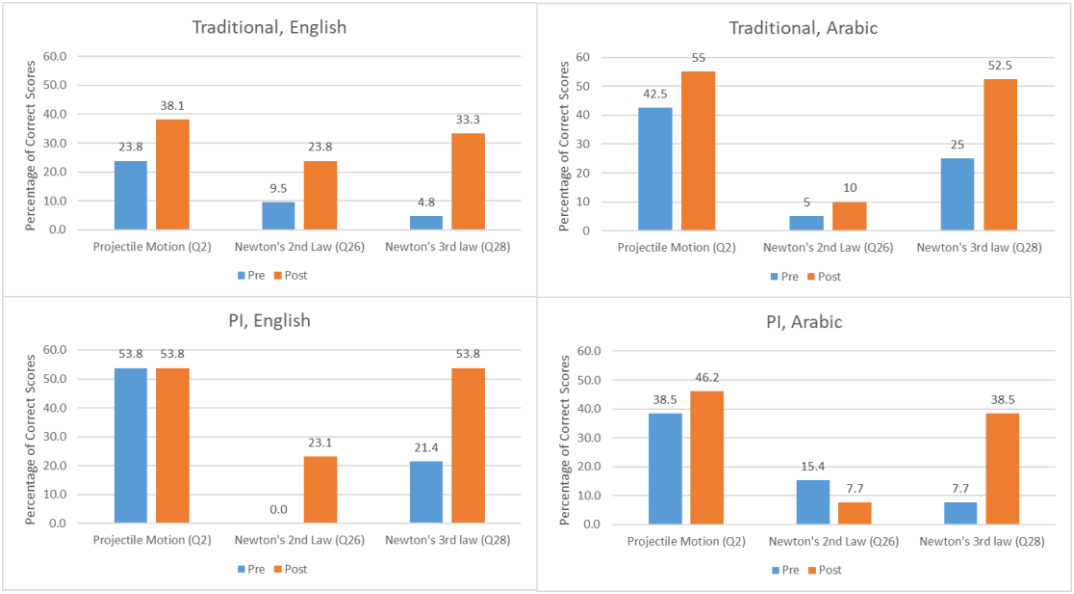


Figure 5-1 The percentage of correct answers for questions 2, 26 and 28 of the pre-and post-Half FCI for all groups and both versions (Arabic and English)

To investigate the performance in the English version further, **Figure 5-2** shows the pre- and post-results of the individual students for each of the three questions, Q2, Q26, and Q28. Interestingly, this figure shows that even when there is an average improvement from Figure 5-1 some individual students still got worse in the post-test.

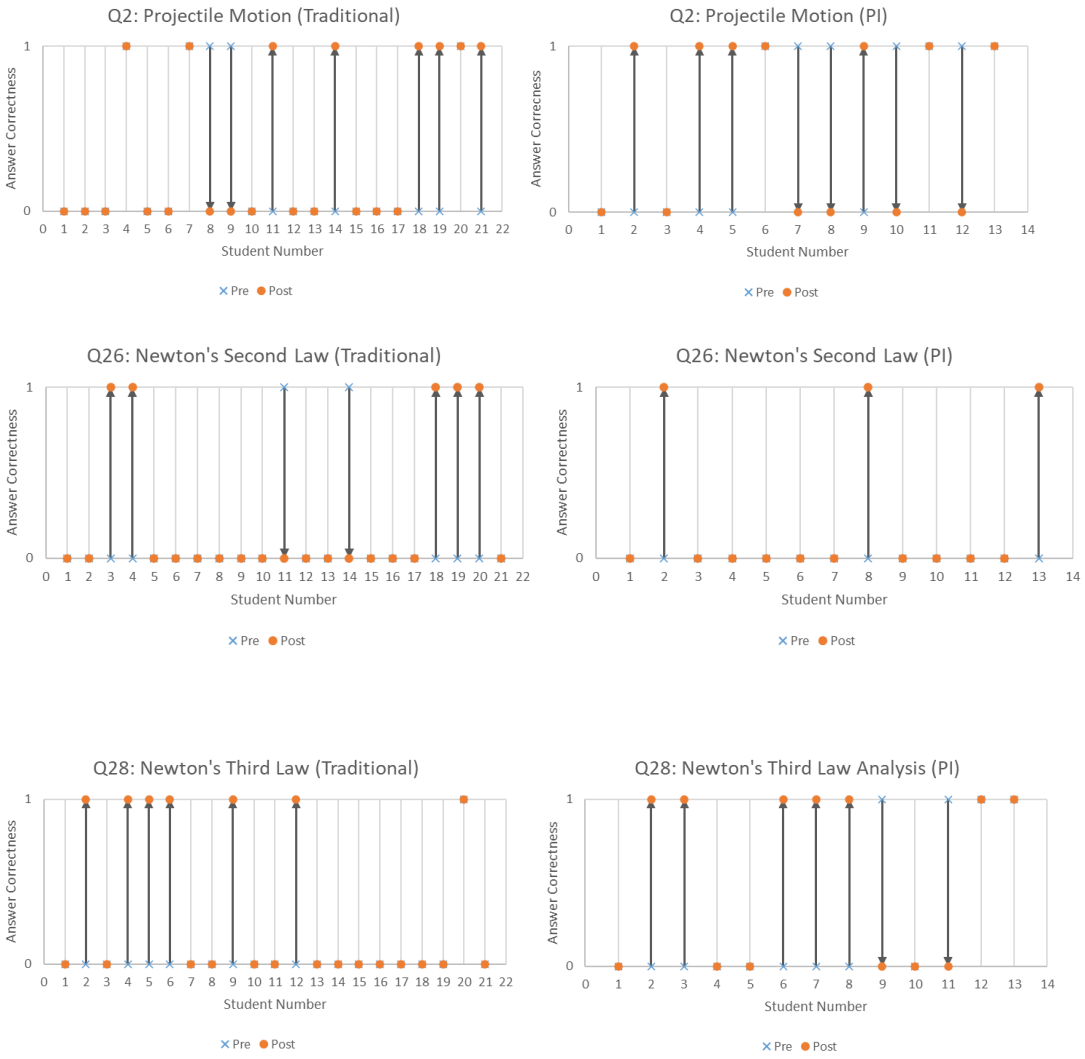


Figure 5-2 The pre-and post-results of the individual students for each of the three questions, Q2, Q26, and Q28.

These three questions (Q2, Q26, and Q28) were further investigated by conducting think-aloud interviews. These interviews are discussed in section 5.2.

5.2 Think-Aloud Interview Findings

The three identical questions of the half FCI, namely Q2, Q26, and Q28, were further investigated by conducting think-aloud interviews.

Students were invited to volunteer for these interviews as part of the post-test of the Half FCI. Later, further invitations were sent to the students who accepted the initial invitation. Four students accepted the invitation to the Peer Instruction online course, and seven students accepted the invitation to the traditional online course; six of them completed the English Half of FCI, and the rest completed the Arabic Half of FCI. Students who did the English version were asked the questions in English first, then in Arabic and vice versa. A summary of the

participants' information is presented in Table 5-6. Fortunately, we had a good gender ratio and a full range of learning gains from negative to maximum.

St No	Course	Gender	HFCI Version	Pre HFCI	Post HFCI	Gain
1	PI	F	English	5	6	0.11
2	Traditional	M	Arabic	4	7	0.3
3	Traditional	F	Arabic	3	6	0.27
4	Traditional	F	English	2	14	1
5	Traditional	M	English	4	9	0.5
6	Traditional	M	Arabic	6	5	-0.13
7	Traditional	M	Arabic	0	2	0.14
8	Traditional	M	English	6	11	0.36
9	PI	F	Arabic	1	4	0.21
10	PI	F	English	None	10	None
11	PI	F	English	3	9	0.43

Table 5-6 A summary of the information provided by the participants who conducted the think-aloud interviews (Note: Student 10 did not do the pre-half FCI).

Below is an analysis of the trends and insights drawn from the students' answers, language-related clarity issues, and their explanations.

Table 5-7 captures students' responses regarding Q2, which describes the horizontal motion of two balls of different weights as they roll off a table with identical initial speeds. This question assesses comprehension of how gravitational acceleration affects horizontal displacement, regardless of mass.

There were a variety of answers in the pre-test, with students choosing A, B, and even E. This distribution suggests a range of misconceptions regarding how gravity affects objects with different masses in horizontal motion.

A (the correct answer) and B are the most common pre-test choices. Students choosing B might believe that mass affects horizontal distance travelled, which reflects a misunderstanding of projectile motion principles.

In the post-test, only a few students correctly answered A. For instance, student 2 consistently chose A, showing correct initial and sustained understanding that both balls hit the floor at approximately the same horizontal distance due to gravity acting equally on both.

On the other hand, many students changed their answers between A, B, C, and D, reflecting confusion that persisted even after instruction. For example, students 1, 4, and 7, initially answered correctly but diverged to D or C in the post-

test, which might suggest uncertainty introduced by the instruction or persistent misconceptions.

To compare between Arabic and English responses, most students maintained consistency across their answers in both languages during the interview, which indicates that language did not significantly alter their understanding of the concept. For instance, student 2 maintained the correct answer A across all contexts, while others like student 5 consistently chose C in the interview, indicating a firm but incorrect understanding.

On the other hand, students 3 and 7 chose different answers for the Arabic and English questions. These students reported that the question was unclear to them and this might affect their responses and make them choose different incorrect answers.

In general, all students who reported that the question was unclear in either language chose incorrect answers. Although most students reported the question as clear, indicating that they understood the scenario and the provided choices, some students ultimately selected incorrect answers, such as students 6, 8, and 10. This may be due to misconceptions rather than a language issue.

To explain their answers, several students used gravitational acceleration or related concepts. For instance, student 1 reasoned correctly in Arabic about gravitational acceleration but chose D in the post-test, suggesting potential confusion over how gravity affects objects of different masses horizontally.

Student 5, who cited

> *“larger weight, larger gravitational acceleration,”*

revealed a misunderstanding by associating greater weight with a stronger gravitational effect on horizontal distance. This indicates confusion between vertical gravitational effects and horizontal motion.

Student 6 inappropriately referenced Newton's First Law by using the formula $v=v_0+at$, which is irrelevant for horizontal distance in projectile motion.

> *“Newton's laws? The first thing I did was find the time. The first equation is: final velocity equals initial velocity plus acceleration times time. Acceleration here is the acceleration due to gravity. So we calculate the time then we calculate distance”*

This indicates a misapplication of concepts.

In general, there was a recurring misconception, which is the belief that heavier objects travel a shorter distance. Students like 7 and 8 believed that heavier objects would experience greater gravitational pull and thus travel less horizontally, not accounting for the separation of vertical and horizontal motion.

Students who chose C or D (e.g., student 11) often did so based on explanations that tied acceleration inversely to mass, which suggests a misunderstanding of the independence of horizontal velocity from mass in this scenario.

The shifts in responses from A to C or D in the post-test (e.g., students 1 and 9) might reflect either confusion introduced during instruction or insufficient emphasis on the independence of horizontal and vertical motions in projectile motion.

The use of mixed Arabic and English terms during explanation (e.g., students 3 and 4) implies that while language did not fundamentally alter conceptual misunderstandings, it may have played a role in expression. For example, students who mentioned projectile motion in both languages (like student 4) may have clearer frameworks but still struggle with full comprehension.

Q2	**Half FCI**		**Interview**			
St No	**Pre**	**Post**	**Arabic**	**English**	**Question Clarity**	**Explanation**
1	**A**	D	**A**	**A**	Clear	Because of gravitational acceleration (Arabic)
2	**A**	**A**	**A**	**A**	Clear	Weight does not affect the horizontal distance (Arabic)
3	B	**A**	D	B	Horizontal motion in Arabic?	W(Arabic) = mg (English)
4	D	**A**	**A**	**A**	Clear	Equations of horizontal and vertical motion of a projectile (A/E)
5	B	B	C	C	Horizontal motion in English?	Larger weight larger gravitational acceleration! (A/E)
6	B	**A**	B	B	Clear	Newton's 1st law: $v=v_0+at$ (A/E)
7	**A**	D	B	D	Options not clear	The heaviest ball experiences larger gravity so it cannot go longer horizontal distance (Arabic)
8	B	D	D	D	Clear	Because the gravity will affect the heavier ball more (Arabic)
9	**A**	C	**A**	**A**	Clear	No relation between horizontal distance and the two masses (Arabic)
10	None	**A**	D	D	Clear	The heavy ball will not move longer distance and will fall quickly (Arabic)
11	E	C	C	C	Distance from the table not clear	Relation between acceleration and mass, which is inversely proportional (Arabic)

Table 5-7 Students' responses regarding Q2 of the half FCI. The correct answer is A (in bold).

Table 5-8 summarises students' responses and reasoning for Q26, which explores their understanding of how an increased constant force affects the motion of a box moving with constant velocity. The table provides insights into the students' pre-test and post-test answers, as well as their answers in the

interviews in both Arabic and English. It also notes question clarity as indicated by students and specific explanations that reveal their thought processes and potential misconceptions.

Interestingly, no students chose the correct answer, E, in the pre-test. Nevertheless, several students shifted to the correct answer, E, in the post-test, showing an increased understanding that doubling the force would lead to continuous acceleration, as the friction remains unchanged.

On the other hand, some students, such as 1 and 5, shifted to incorrect answers post-test.

When asked about the question's clarity, student 1 mentioned confusion over the term "thereafter," indicating a possible issue with the phrasing of the question or the sequence of events described.

Student 5 questioned friction, which suggests a misinterpretation of the role friction plays in relation to continuous acceleration versus maintaining constant velocity.

Most students reported the question as clear yet still provided incorrect answers or explanations. This suggests that their misunderstandings were more conceptual than linguistic, as they understood the question but misapplied principles like friction and acceleration.

Students like 9 and 10 appeared to be clear on the question itself but struggled with applying Newton's laws to the situation, showing confusion between concepts of constant velocity and acceleration.

Multiple students, such as 1, 2, and 8, referenced $F=ma$, but some misinterpreted this, equating force directly with speed rather than acceleration over time. For instance, Student 1's explanation that

"force is directly proportional to speed"

reflects a common misconception.

Student 10's statement,

"If I applied a force, velocity would increase. I don't know why it became constant!" reflects an incomplete understanding. This student seems to realise that increased force should alter motion but does not connect this with continuous acceleration due to unbalanced forces.

Student 11's explanation that

"a bigger force will make it faster"

highlights an intuitive response that disregards the role of continuous force in sustaining acceleration rather than achieving a new constant speed.

Despite the shift towards E in the post-test, several students retained or developed misunderstandings post-instruction, as indicated by their answers in the interviews. For example, students 1,7,8 and 11 answered correctly in the post-test but not in the interview. Moreover, Student 3 answered correctly in one language but incorrectly in the other, showing potential issues in conceptual consistency when switching languages.

Q26	**Half FCI**		**Interview**			
St No	**Pre**	**Post**	**Arabic**	**English**	**Question Clarity**	**Explanation**
1	A	**E**	B	B	Thereafter?	F=ma=m (v/t) (force is directly proportional to speed) (A/E)
2	A	A	A	A	Clear	Newton Law (Arabic) F=ma (English)
3	A	C	**E**	A	Clear	F=ma (in Arabic) Used (Equal) in English
4	A	**E**	**E**	**E**	Clear	Used Newtons 2nd law and friction force (A/E)
5	D	A	A	A	Friction?	Newton's 2nd law (Arabic) F=ma (English)
6	D	B	B	B	Clear	Work law(Arabic) W=FD=0.5mv^2 (English)
7	A	**E**	D	B	Clear	Used Newtons 2nd law and friction force (A/E)
8	A	**E**	A	A	Clear	Newton's 2nd law (Arabic) F=ma (English)
9	B	**E**	**E**	**E**	Confused force and constant velocity!	If there is force, there is acceleration therefore velocity is changing (Arabic)
10	None	A	D	D	Clear	If I applied a force, velocity would increase. I don't know why it became constant! (A/E)
11	B	**E**	A	A	Clear	Imagination: if you push an object with a bigger force it will move faster (Arabic)

Table 5-8 Students' responses regarding Q26 of the half FCI. The correct answer is E (in bold).

Table 5-9 summarizes student responses and explanations for Q28, which assesses their understanding of Newton's Third Law of Motion. The question scenario involves two students pushing off each other, testing whether they recognize that the forces they exert on each other are equal and opposite. Below is an analysis based on the pre-test and post-test answers, Arabic and English responses in the interviews, question clarity, and student explanations.

Most students who initially answered incorrectly on the pre-test (e.g., B or D) moved to the correct answer E in the post-test. This reflects an improved understanding that each student exerts an equal and opposite force on the other regardless of their individual masses, consistent with Newton's Third Law.

Several students consistently answered E across all settings, including 3, 8, and 10, demonstrating a stable understanding of Newton's Third Law.

Most students found the question clear, indicating that they understood the scenario and what was being asked. This suggests that their responses primarily reflect a conceptual understanding rather than confusion about the question wording.

Student 7 was an exception, expressing uncertainty about

> *“which student pushed the other,”*

which may imply some difficulty understanding the scenario or interpreting the actions taking place.

Many students referenced Newton's Third Law directly, confirming their understanding of the principle that forces between two interacting objects are equal in magnitude and opposite in direction.

Student 8 drew an analogy from a lecture involving a butterfly and a truck, which might have been used to illustrate how force interactions occur regardless of size differences. This example helped solidify their grasp of equal and opposite forces.

While most students correctly identified Newton’s Third Law, Student 7 was uncertain between the second and third laws, showing some confusion about which law directly applies to the scenario. This may reflect a partial understanding, as they recognized the action-reaction concept but were unsure of its formal categorization.

Nearly all students demonstrated a stable understanding of Newton's Third Law across both languages, with explanations provided in Arabic and English that maintained the same meaning. This suggests that language did not pose a significant barrier to their comprehension of the concept.

The instruction clearly helped students identify the correct answer. Students who shifted to E post-instruction displayed a better grasp of action-reaction forces, which indicates that the instruction, whether traditional or PI, effectively reinforced Newton’s Third Law.

Q28	Half FCI		Interview			
St No	Pre	Post	Arabic	English	Question Clarity	Explanation
1	D	**E**	**E**	**E**	Clear	Newton's 3rd law (Arabic)
2	**E**	B	**E**	**E**	Clear	Newton's 3rd law (Arabic)
3	**E**	**E**	**E**	**E**	Clear	Newton's 3rd law (English)
4	D	**E**	**E**	**E**	Clear	Newton's 3rd law (Arabic)
5	B	**E**	**E**	**E**	Clear	Newton's 3rd law (Arabic)
6	B	**E**	**E**	**E**	Clear	Newton's 3rd law (Arabic)
7	D	**E**	D	D	which student pushed the other?	Newton's 2nd or 3rd law! (Arabic)
8	**E**	**E**	**E**	**E**	Clear	Example during a lecture (a butterfly hits a truck) (Arabic)
9	D	D	**E**	**E**	Clear	Newton's 3rd law (Arabic)
10	None	E	**E**	**E**	Clear	Newton's 3rd law (Arabic)
11	D	E	**E**	**E**	Clear	Newton's 3rd law (Arabic)

Table 5-9 Students' responses regarding Q28 of the half FCI. The correct answer is E (in bold).

To do further analysis, these interviews were transcribed and analysed using thematic analysis. Two interviews were translated by me and separately coded by me and each supervisor to ensure the validity and reliability of the analysis. Discussion between the three of us brought agreement on the themes and codes in Figure 5-3 and the rest of the interviews were analysed accordingly.

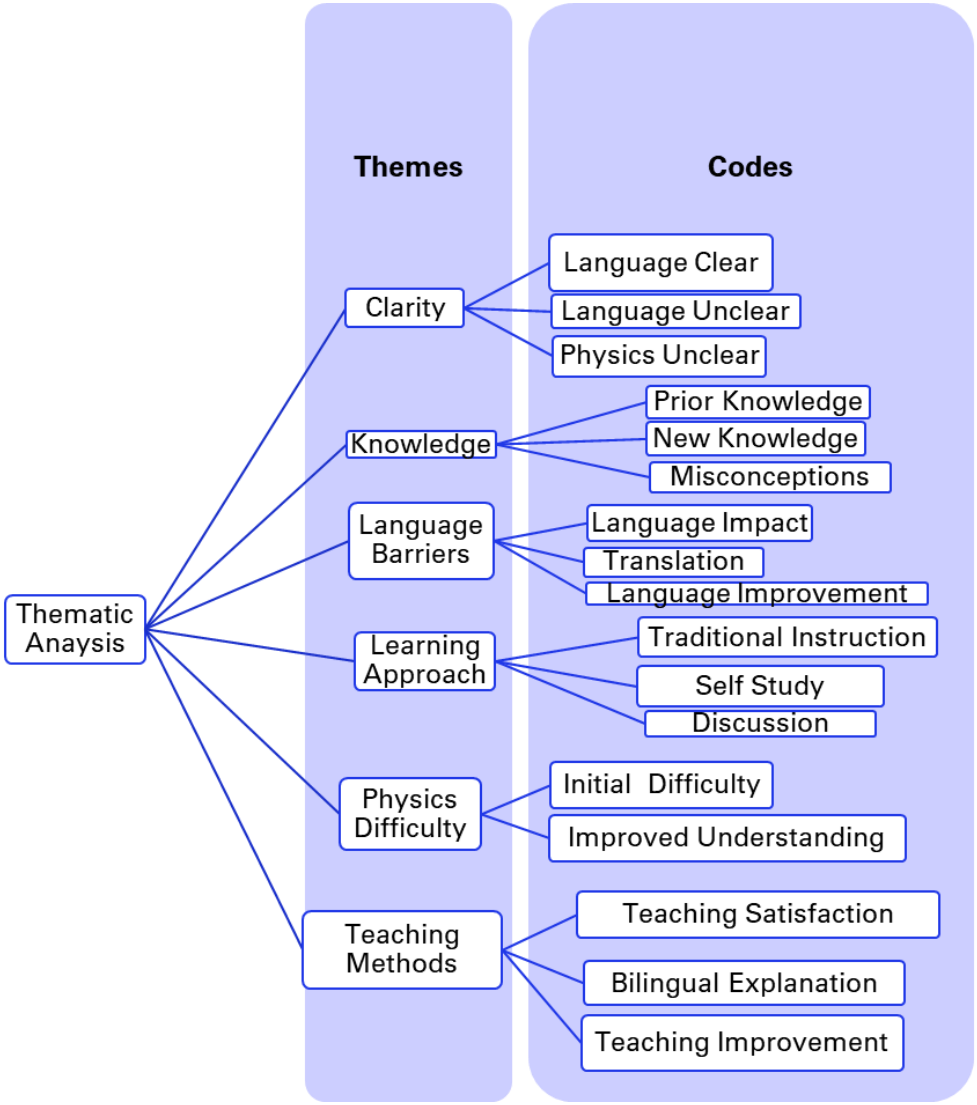


Figure 5-3 The themes and codes that emerged from the think-aloud interviews.

5.2.1 Questions Clarity

Many students found the language of questions to be clear, regardless of whether the question was in Arabic or English. These students reported understanding the questions without difficulty, as noted in multiple instances where students confirmed their comprehension with no issues.

Several students also noted that Arabic questions were clearer and easier to understand than those in English such as students 1 and 5.

Despite overall clarity, some students faced language difficulties in specific instances, particularly with English questions. For example, terms such as “distance from the table” in question 2 or phrases like “constant speed thereafter” caused confusion for students 1 and 11, suggesting potential gaps in understanding technical language in English.

Certain Arabic questions also posed challenges, especially where terminology may differ from everyday language, such as “horizontal motion” not being immediately clear to student 3.

Besides language, there were occasions where students expressed uncertainty about the physics concepts rather than the language itself. Student 5, for example, expressed confusion about the physics concept used in Q28

> *“the question is clear but is there friction?”*

And also, student 9

> *“If there is force, there is acceleration therefore velocity is changing. Velocity cannot be constant!”.*

5.2.2 Knowledge of Physics Concepts

By analysing answers to Q2, multiple misconceptions regarding weight and gravitational acceleration were identified. Some students incorrectly still believed that heavier objects experience greater gravitational acceleration and would thus fall faster or cover less horizontal distance. For example, student 3 said

> *“The heavier ball is slower due to its weight and covers a shorter distance. On the other hand, the lighter one covers a greater distance”,*

student 7 said

> *“The heaviest ball experience larger gravity so it cannot go longer horizontal distance”*

and student 10 said

> *“The heavy ball will not move longer distance and will fall quickly”*

Moreover, some students still used intuitive reasoning that contradicted the physics principles they had studied in the physics course. For example, some assumed that heavier objects would fall faster due to gravity such as student 5 *“Larger weight larger gravitational acceleration!”.*

By analysing answers to Q26, many students misapplied Newton’s Second Law and they had incorrect beliefs about horizontal motion and force, such as thinking that increasing force will always increase velocity, or that velocity is affected directly by force rather than by acceleration such as students 1 and 10. They stated that

> *“Because of F=ma=m (v/t) then force is directly proportional to speed”*

and

“If I applied a force, velocity will increase. I don’t know why it became constant!”. This reflects a fundamental misunderstanding of how force, mass, and acceleration interact.

Even though only two students have chosen the correct answer to this question correctly, one of them answered it with the wrong reasoning such as student 9, who was confused with having force and constant velocity

> *“If there is force, there is acceleration therefore velocity is changing”*

In terms of Newly Learned Knowledge, the following was observed from the interviews.

In Q2, some students demonstrated an accurate understanding of acceleration due to gravity, recognizing it as a consistent factor affecting falling objects, regardless of their mass such as student 1

> *“Because of gravitational acceleration” and student 2 “Weight does not affect the horizontal distance”.*

For Q26, it seems that physics instruction benefited student 4 only who answered correctly with accurate reasoning by using Newtons second law and friction force.

On the other hand, many students correctly applied Newton’s Third Law as indicated by their answers and reasoning of Q28. This indicates that students had acquired a sound understanding of action-reaction forces, perhaps due to recent university instruction as they frequently mentioned in the interviews such as student 8 who got the knowledge

> *“From example during the lecture which was about a butterfly hits a truck”.*

In general, several students reported feeling more knowledgeable and skilled after studying physics at the university level, indicating a growing confidence in their understanding of concepts compared to the beginning of the semester.

Moreover, there were indications that some students had a solid pre-existing understanding of Newton’s Third Law, possibly reinforced by prior experiences or school education such as student 3

> *“Newtons Third Law is deep-rooted on us"*

5.2.3 Language Barriers

At the beginning of the physics course, students commonly experienced difficulties when answering questions in English, particularly in comparison to Arabic. They found themselves needing more time to process English questions

due to unfamiliar physics terminology and general language barriers. Student 11 reported

> *“It was very difficult at the beginning because of language. I understand faster in Arabic, but I need more time in English.”*

Some students highlighted how the language challenge impacted their physics learning. Student 11, for example, stated that she felt more comfortable with physics concepts in Arabic, her native language. This suggests that language can be a barrier to grasping physics content when it is taught in a non-native language.

To understand physics better in English, some students often relied on translating English questions into Arabic, especially when encountering complex terms or unfamiliar words such as student 1

> *“Most of the time I need to translate then solve them”*

and student 2

> *“I translate only if there are unclear key words to understand the questions”.*

While some found translation necessary, others viewed it as time-consuming and potentially distracting, especially for those who had begun to prefer thinking directly in English such as student 3

> *“I don’t translate to Arabic at all. Impossible! Waste of time! If you have the basics and the concepts you can solve any question!”.*

Over the semester, many students noted an improvement, as repeated exposure to English physics terms helped them adapt. With time, they found the post-test somewhat easier to comprehend in English than the pre-test such as student 7 *“But at the end of the semester it was easier*

to understand the questions in English and I needed

to translate only a few words”

and student 11

> *“It was easier from the side of language because I learned the words in English.”.*

This progression demonstrates how language adaptation can occur with sustained exposure, even though it remains a challenge at the beginning. Student 11 reported,

> *“The repetition of physics terms over the semester made it easier to understand them”.*

5.2.4 Physics Difficulty

Many students found the pre-test challenging due to a lack of recent exposure to physics or gaps in their prior knowledge. They had not studied physics for a significant period before joining university, which contributed to their struggle with the subject initially. Student 11 reported that

> *"Physics was also difficult because we didn't study physics for long time even though I liked physics at school"*

Some students mentioned external factors that contributed to their difficulty with the pre-test, such as rushing through the test due to other academic commitments or adjusting to the new learning environment at the university such as student 3 *"I was busy with other courses and solved the pre-test with rush".*

Few students indicated that their initial difficulties were primarily due to physics concepts themselves rather than language barriers. For example, even with the pre-test administered in Arabic, some students still found the physics content itself unclear, highlighting their struggle with conceptual understanding such as student 2

> *"Even though I took the pre-test in Arabic, the test was unclear from the physics side!"*

By the time of the post-test, students noted that their understanding of physics improved. They attributed this to gaining foundational knowledge through lectures, which helped them grasp basic concepts and made the post-test easier compared to the pre-test. Student 2 said

> *"But the post-test was clear from the physics side"*

and student 4, who got full mark in the post-test, said,

> *"It was easier from the side of physics because I learned the basic concepts."*

However, student 7, who conducted the post-test in Arabic, mentioned that the second test was easier in terms of physics but still had some language difficulties because he used to study physics in English during the semester.

5.2.5 Learning Approach

Traditional instruction methods, including lectures and explanations from the instructor, were highlighted as valuable for understanding physics concepts. All students from the traditional instruction group and three out of four students from the PI group cited lectures as a primary source of learning, with several attributing their understanding directly to explanations provided by the instructor.

Specific examples, such as the explanation of Newton's third law with a relatable example (e.g., butterfly hitting a truck) were particularly impactful for the traditional group with only 1 student out of seven got it wrong in the interview. These instructor-led explanations helped students visualise and comprehend abstract concepts by connecting them to real-life scenarios.

On the other hand, some students emphasised the importance of self-study as a method of learning. They relied on their individual effort and time spent reviewing the material to understand and recall physics concepts. Self-study was also noted as a significant factor in preparing for the tests, particularly for students who found the subject challenging like students 2, 5 and 6 from the traditional instruction group and students 1 and 9 from the PI group.

Only two students mentioned that discussing with peers during class or with classmates outside of class helped them answer specific questions and understand concepts better. These are student 1 from the PI group and student 2 from the traditional group. Peer discussions provided them with alternative perspectives and reinforced their understanding of some topics.

Some students indicated that there were limited opportunities for discussions during lectures, particularly when the online Peer Instruction (PI) system did not function as expected. This lack of interaction may have limited the potential benefits of peer discussions for these students during COVID time.

5.2.6 Teaching Methods

Many students expressed satisfaction with their physics instructors, whether they teach traditionally or by PI. PI students appreciated clear explanations, discussions and real-life applications of concepts. They found that these aspects contributed to their overall understanding and engagement. Student 1 reported,

> *“I found it helpful when the instructor connected physics concepts to real-life situations”,*

and Student 10 said,

> *“Instructor explanations, discussions, and lectures helped me understand and solve the questions.”*

On the other hand, the traditional group student 9 acknowledged that their instructor maintained effective communication with students and allowed them to freely ask questions and she considered that as a key component of good teaching.

Students also valued when instructors provided opportunities for discussion and when they could comfortably seek clarification on complex topics. The traditional

group student 4 also appreciated the teaching style of the instructor and mentioned that she effectively conveyed the information and provided opportunities for questions and discussions. Student 6 expressed a high degree of satisfaction with the teaching and mentioned that he gives a full mark to his physics instructor!

While students were generally satisfied with the teaching, some emphasized the importance of their own effort in understanding and learning. For example, PI student 9 acknowledged that the teaching was effective but also noted that self-initiative played a significant role in their academic progress.

Regarding the language of teaching, students 2, 8 and 10 appreciated when instructors used both Arabic and English to explain physics concepts. They felt that this approach solidified their understanding by providing familiar linguistic context and bridging any comprehension gaps.

Moreover, students highlighted that explanations in Arabic were particularly helpful, especially when introducing new terms or complex concepts, or clarifying difficult terms or concepts. Some suggested that learning physics in Arabic would make it easier to relate to real-life applications and save time as it reduces the need for translation.

Regarding teaching improvement, students expressed their need for more practice problems, interactive tutorials, problem-solving activities, and hands-on experiments. They felt that these methods could aid in comprehension, as opposed to a more passive learning approach.

Surprisingly, students also preferred traditional methods like handwritten notes over digital resources, feeling that this approach helped them stay focused. They also noted the importance of minimizing distractions during online classes and creating an environment helpful to learning.

5.3 Analysis of CLASS Survey Data

The Colorado Learning Attitudes about Science Survey (CLASS) is an instrument designed to measure students’ attitudes and beliefs about learning physics. It is commonly used as a pre-test and post-test in physics courses to measure shifts in students' attitudes and beliefs after exposure to different teaching methods, such as traditional lecture-based instruction versus active learning or peer instruction.

CLASS data can also be correlated with other performance measures, like conceptual tests (e.g., FCI), to explore how attitudes affect or relate to learning gains (K. K. Perkins et al., 2008). Using the CLASS survey alongside the FCI can

provide a more holistic understanding of how the instructional methods (traditional vs. PI) impact conceptual understanding and influence students' attitudes toward learning physics.

In this study, an online CLASS survey was administered for the two groups who did the English Half FCI to compare their learning gain in the language they were taught with their improvement in attitude toward physics and give a broader view about the effect of the teaching approach. To analyse these data, the Excel template provided by the developers of CLASS (Adams et al., 2006) was used. This template is available at www.physport.org.

The overall pre and post percentage favourable responses for CLASS in Spring 2021 are presented in Table 5-10. It is noticed that traditional (Engineering) students had higher pre-scores than the PI (Science) students. A similar observation in the dependence of major was observed in a Saudi study (Alhadlaq et al., 2009).

Therefore, a possible reason for the higher pre-scores of Engineering students is that they have signed up to take a course that values physics and its applications, and thus, they have a positive view of physics and its methods. This is supported by the literature that indicates that students' majors are strongly related to their attitude toward physics (Perkins & Gratny, 2010; Slaughter et al., 2011). On the other hand, students of the Physics for Science course will go on to study Agriculture, Education, and other science disciplines, so they may be less interested in the nature of physics and see this as just a requirement to get into their chosen discipline. However, it is clear that the teaching method has very

little effect on attitudes to science in this context compared to literature (P. Zhang et al., 2017).

Table 5-10 also shows that traditional (Engineering) students got a more positive shift compared to PI (Science) students. A study in the UK got a similar finding for physics students taught with an interactive method, and their shift in attitude was negative as well (Slaughter et al., 2011). This is in contrast to literature where Chinese students got a positive shift in PI courses and a negative shift in the traditional course (Zhang et al., 2017). The major of the Chinese students was geology and chemistry.

Class	No of Students	Pre	Post	Shift (St Error)
Traditional (Engineering)	21	61.1 (2.9)	64.1 (2.5)	3.0 (1.9)
PI (Science)	15	48.7 (4.4)	49.4 (3.4)	0.7 (3.4)

Table 5-10 The overall pre and post percent favourable responses for CLASS for traditional teaching and PI students in Spring 2021

The effect of gender is shown in **Table 5-11.** Nevertheless, the effect of students' major is the most noticeable difference, with higher pre scores for engineering students than for Science students.

The shifts for all groups are small, with female science students even recording a negative shift. However, these shifts are not distinguishable within the errors. This is in contrast to the study by Zhang et al (2017), who reported a negative shift for female students on their traditional course compared to a positive shift on their PI course.

	Females				**Males**			
Class	**No of Students**	**Pre**	**Post**	**Shift**	**No of Students**	**Pre**	**Post**	**Shift**
Traditional (Engineering)	7	59.6	63.3	3.6	14	61.9	64.5	2.6
PI (Science)	8	51.4	50.7	-0.7	7	46.1	48.0	1.9

Table 5-11 The overall pre- and post-per cent favourable responses for CLASS for traditional teaching and PI students separated by gender.

In Table 5-12, the different categories of CLASS are compared for the PI and traditional courses. It is noted that students in the traditional course experienced a positive shift in all categories except for Problem-Solving Sophistication. In contrast, students of the PI course got a negative shift in all categories except for Sense Making and Effort. This is in contradiction to the Chinese students, who experienced negative shifts in all categories in the traditional group and positive shifts in all categories in the PI groups.

	Traditional (Engineering)			PI (Science)		
Categories	**Pre**	**Post**	**Shift**	**Pre**	**Post**	**Shift**
Personal Interest	73.0	75.4	2.4(3.9)	55.4	50.0	-5.4(6.5)
Real World Connection	70.2	72.6	2.4(4.4)	54.7	50.0	-4.7(9.2)
Problem Solving General	76.0	77.3	1.3(2.4)	62.8	58.6	-4.2(6.7)
Problem Solving Confidence	71.4	78.6	7.1(5.1)	64.1	56.3	-7.8(6.1)
Problem Solving Sophistication	61.6	56.3	-5.2(5.1)	46.1	35.6	-11.3(7.1)
Sense Making or Effort	72.8	74.6	1.8(3.8)	58.9	61.0	2.1(6.0)
Conceptual Understanding	55.6	63.5	7.9(6.3)	44.2	39.6	-4.6(6.9)
Applied Conceptual Understanding	40.8	49.0	8.2(4.5)	35.7	28.7	-7.0(6.1)

Table 5-12 Scores on % of each category of pre and post-CLASS of traditional teaching and PI students.

5.4 Summary and Integration of Results

This chapter explored the impact of different teaching methods on students' learning gains and attitudes towards physics, specifically comparing traditional teaching with peer instruction (PI) during Spring 2021, a period of online learning due to COVID-19. The study utilized pre- and post-Half FCI assessments, think-aloud interviews, and CLASS surveys to collect data.

The study involved Engineering and Science students, with the former taught by traditional teaching and the latter taught by PI.

Pre- and post-half FCI scores indicated low normalized gains for both groups, with Engineering students showing a normalized gain of (0.22±0.08), while Science students had a normalized gain of (0.13 ± 0.08). No significant difference was found between the two teaching methods.

When comparing results based on language, students who conducted the test in Arabic had lower gains than students who conducted the test in English. However, the differences were not statistically significant.

Male students had a normalized gain of (0.10±0.03), while female students scored slightly higher with a gain of (0.15±0.06). However, these differences were not statistically significant.

The three identical questions in the pre-and post-Half FCI revealed persistent misconceptions among students regarding gravitational effects and Newton's laws, regardless of language.

Think-aloud interviews highlighted that many students struggled with physics concepts, often attributing misunderstandings to language barriers or confusion over terminology.

Moreover, students expressed that traditional teaching methods, including lectures, were effective for understanding physics concepts. However, self-study and peer discussions were also noted as important for reinforcing learning.

Many students reported improved confidence and understanding of physics over the semester, particularly in applying Newton's Third Law.

The CLASS survey indicated that traditional instruction resulted in a more positive shift in students' attitudes compared to PI, though both groups exhibited minimal changes overall.

Gender differences were noted, with female Science students experiencing a slight negative shift in attitudes.

Overall, while both teaching methods led to improvements in student understanding, traditional instruction appeared to yield slightly better outcomes in terms of learning gains and attitudes towards physics. The chapter concludes that language and prior knowledge can impact student performance and understanding of physics.

Chapter 6

Effect of Language and Culture on Peer Instruction

This chapter aims to explore the influence of language and culture on the effectiveness and implementation of peer instruction practices. The focus is on answering research question 3: How do language and cultural factors affect student-student and student-teacher interactions? And Research question 4: What are the students' and teachers' perspectives about peer instruction?

To achieve this goal, the findings derived from interviews conducted with teachers and students are presented. The focus was on examining the role of language and culture in shaping peer interactions and instructional practices within peer instruction.

6.1 Interviews with Teachers:

Teachers' interviews offer valuable insights into how language and cultural factors influence student-student and student-teacher interactions in the context of Peer Instruction (PI) in introductory physics courses. The findings from interviews conducted with teachers are presented, focusing on their perceptions and experiences with peer instruction in the context of language and culture. Moreover, teachers' strategies for facilitating student-student interactions in bilingual classrooms and addressing language barriers to promote effective communication and collaboration among students are highlighted.

Teachers with experience in Peer Instruction were invited to the interviews. All nine teachers who were invited accepted the invitation. Their experience with Peer Instruction ranged from less than two to over five years. There was a roughly equal split between male and female teachers. Most teachers were native Arabic speakers.

6.1.1 Theme 1: Language and Student-Student Interaction

Analysing the teachers' interviews led to a key theme about "Language and Student-Student Interaction." This theme highlights some aspects of the relationship between language proficiency and student engagement in bilingual classrooms. It resulted in three principal codes: English Language Barriers, Peer Discussions in Arabic, and Code-Switching. These codes are discussed below.

Code 1: English Language Barriers

Some teachers mentioned that students' reluctance to participate in classroom discussions is sometimes due to their English language proficiency, with some students fearing embarrassment due to mistakes. This highlights the role of language barriers in limiting student engagement. For example, Teacher 1 said:

> *"Some of them like they have difficulties in English being quiet or not participating is because their English is not good or they are not able to explain it in a clear way, or they are feeling like they're going to get embarrassed."*

Code 2: Peer Discussions in Arabic

Although English is the formal language of instruction, many teachers have observed that Arabic is frequently used by students during group discussions, particularly when clarifying complex concepts or when they are uncertain about using English. For example, Teacher 3 stated,

> *"When discussing with their friends during group work, they use Arabic."*

In general, teachers support this practice, recognising the need for flexibility in language use for the sake of comprehension, which they consider the most important aspect, as teacher 3 stated

> *"When they are discussing Arabic, I think it will be more effective for them."*

Teachers also acknowledge the comfort students feel when discussing in their native language, particularly when explaining complex concepts. Many teachers tend to be flexible, allowing Arabic to be used as long as the students' comprehension and learning progress are considered. For example, Teacher 6 said,

> *"Whichever language is comfortable for learning, let them use it."*

Code 3: Code-Switching

Code-switching, where students alternate between Arabic and English, is a common practice that teachers notice, particularly in group discussions between students. While students may explain concepts in Arabic, they often switch to English for technical terms in physics or when writing in the answer sheets. Teacher 3 said

> *"Many students when they discuss it is not pure Arabic. They mix Arabic with English."*

Some teachers like Teacher 1 encourage this practice of code-switching

“I tell them if you do not know how to say it in English say it in Arabic... So at least they combined English and Arabic as they have difficulty with English”

In summary, these codes reflect the complexities of language use in the physics classroom and highlight how language proficiency could impact students’ engagement, peer interactions, and overall learning outcomes. These findings underscore the significance of understanding language use in a bilingual educational setting, particularly where English is the medium of instruction, but students mainly speak Arabic.

6.1.2 Theme 2: Language and Student-Teacher Interaction

The analysis of the data collected from the teachers’ interviews revealed some aspects of “Language and Student-Teacher Interaction”, particularly in a bilingual educational context where English serves as the primary medium of instruction. The findings in this theme are organised around four main codes: English Language Barrier, Bilingual Interaction, English Reinforcement, and Simplifying English. Each code highlights specific challenges and strategies teachers employ to navigate the complexities of language use in their classrooms. These codes are discussed below.

Code 1: English Language Barrier

Some teachers mentioned that language barriers remain a significant obstacle, particularly for new or complex vocabulary and lengthy sentences. Students often struggle initially with unfamiliar terminology and sentence structures, which affects comprehension. Teacher 8 stated that students often stop them during instruction:

“Doctor, please just go slower, because I even don't know what the velocity is.”

However, they added that,

“This English barrier is only the beginning of the first few weeks...”

Teacher 5 also emphasized that:

“One of the major challenges is the long sentences... they have difficulty to correlate the information.”

Some teachers reported that while English is not the students' first language, they do not encounter significant issues with communication when using peer instruction (PI) methods. Teacher 2 said

> *"English is not their mother tongue, but I haven't faced many issues in communication when using PI questions."*

This could be due to the collaborative and interactive nature of PI, which allows students to rely on their peers and native language for support while still engaging with the material in English.

While language barriers exist, some teachers perceive them as manageable, especially when instruction focuses on broad conceptual understanding. Teacher 4 stated,

> *"Yes, language is an issue but might not be as big an issue as we think."*

They also added that:

> *"It does make life more complicated slightly but considering that the aim of PIs is usually to look at broad concepts."*

Teacher 6 acknowledged that while he did not receive any complaints about language barriers from students, it is possible that students are experiencing some difficulties, which they are not expressing clearly.

> *"I haven't received any complaints about language barriers, but there might be some hidden struggles."*

This indicates the need for teachers to be aware of any potential language struggles, even when students do not express them clearly.

Many students mentally translate English material into Arabic to better understand it, which may slow down their learning process and create additional cognitive load. Teacher 4 noted,

> *"They will always end up mentally at least translating every single statement and question into Arabic."*

Code 2: Bilingual Interaction

Bilingual interactions between Arabic-speaking teachers and students are common. While English is often the primary language of instruction, some teachers allow or respond to Arabic when students face challenges in using

English. Teachers and students frequently switch between English and Arabic during interactions according to their needs. While some students prefer Arabic for explanations, they may revert to English for specific technical terms or formal discussions. Teacher 1 reported

> *“For me, I speak with them in English in the class. They sometimes will speak in Arabic... they try to explain it in English, but they are stuck so they talk in Arabic.”*

Teachers primarily use English as the language of instruction, but they sometimes incorporate Arabic when students struggle to grasp specific terms or concepts. This approach helps bridge the comprehension gap without entirely shifting away from the main language of instruction.

> *“Yes, mostly like English. Sometimes I use Arabic just to describe a word.” (Teacher 1)*
>
> *“Yeah, sometimes we can feel it from their eyes… we don't understand...I would explain it to them in Arabic.” (Teacher 1)*
>
> *“If they don't understand after repeating, I switch to Arabic.”*
>
> *(Teacher 3)*
>
> *“Most of the time I use English... only sometimes I explain in Arabic.” (Teacher 3)*

Several teachers note the institutional pressure to maintain English as the dominant language of instruction, but they also emphasize the practical need for Arabic in certain situations. Teachers are often balancing their desire to reinforce English with the practicalities of maintaining communication and comprehension.

Teacher 9 said

> *“At times I would have to use Arabic but I am trying to cut down the Arabic a lot... At least 90% should be in English.”*

Teachers observed that using Arabic, particularly when interacting with female students, can significantly boost participation. This suggests that language choice plays a role in creating a more inclusive and comfortable environment for students. Teacher 8 said

> *“When I speak specifically in Arabic to the students, I feel they become more active...especially the girls.”*

Some teachers perceived Arabic as a quicker means of communication for complex ideas, especially when introducing new terminology. Teachers make use of this by occasionally translating or summarizing complex information in Arabic to help students process concepts more efficiently.

> *"They will understand it much faster... They will tell me like if this lecture was in Arabic, they will understand it much easier."*
>
> *(Teacher 1)*
>
> *"If I am introducing a new terminology, I would use the Arabic translation. I think that by doing so...it makes it easier and faster for me to...deliver the concept...for students" (Teacher 8)*

Code 3: English Reinforcement

Students often use Arabic to answer questions or ask for clarifying concepts, but teachers encourage them to formulate their responses in English as part of reinforcing English proficiency. Teacher 7 reported,

> *"I understand their question in Arabic but ask them to formulate it in English."*

While some teachers show flexibility in language use during informal discussions with students to express themselves in Arabic, when necessary, they emphasize the importance of switching to English during formal academic settings, to reinforce its use as the primary language of instruction. Teacher 4 reported

> *"They attempt to discuss in Arabic... I might engage in Arabic, or I might ask them to say it in English... in a formal class thing I would ask them to say it in English."*

While teachers recognized the benefits of using Arabic for clarification, there is still an emphasis on maintaining English consistency to align with course requirements and build students' familiarity with scientific English.

> *"I think it's better to deliver it in English, especially they are studying the material in English." (Teacher 2)*
>
> *"Usually in a formal class thing, I would ask them to say it in English so that they would get better used to... the language itself."*
>
> *(Teacher 4)*

Code 4: Simplifying English

There is an intentional effort, especially by non-Arabic-speaking instructors, to simplify English language use in instruction and assessments. By using straightforward language, shorter sentences, and avoiding complex vocabulary, teachers help reduce the cognitive load on students, allowing them to focus more on content rather than language difficulties.

> *"We are trying to simplify the English used in our assessment and lectures." (Teacher 2)*
>
> *"I try to use simple English and repeatedly say things if they don't understand." (Teacher 6)*
>
> *"We try to make the language as simple as possible...we are not testing their language; we are testing their physics." (Teacher 8)*

Visual aids like PowerPoint presentations were mentioned by teachers as a means to reinforce spoken explanations, providing another layer of understanding. Visuals are particularly effective for students who may struggle with the listening process in a non-native language.

> *"Whatever we are talking about is displayed on the PowerPoint." (Teacher 6)*

Overall, this theme illustrates the complex dynamics of language and student-teacher interaction within a bilingual educational context. While language barriers present significant challenges, teachers employ a range of strategies, including bilingual interaction, reinforcement of English, and simplification of language, to facilitate comprehension and engagement among students.

6.1.3 Theme 3: Culture and Student-Student Interaction

The theme of "Culture and Student-Student Interaction" emerged prominently from the qualitative data gathered in the teachers' interviews, revealing significant insights into how cultural norms and gender differences shape classroom dynamics. The findings emphasise the complexity of student interactions, particularly in the context of gender, and highlight the role of cultural expectations in influencing these dynamics. This section presents detailed findings around the key codes identified in the analysis: Classroom Seating Arrangements and Participation, Gender Dynamics in Classroom Discussions and Academic Performance and Gender Engagement.

Code 1: Classroom Seating Arrangements and Participation

Classroom seating arrangements, particularly where female students sit in the back, can influence their participation or interaction levels. The seating position may affect visibility, access to the teacher, or the level of engagement in class activities. Teacher 1 reported,

> *"Sitting in the back has an effect..."*

Some teachers highlighted the cultural norm of gender segregation within group activities. Male and female students naturally tend to work with their same gender, a behavior likely shaped by broader cultural norms that encourage gender separation in social and educational settings. Teacher 7 said

> *"Male and female students tend to work within their gender groups."*

This cultural factor prevents males and females from engaging in discussions together. Teachers attributed this separation to broader cultural norms that discourage interaction between male and female students in educational settings. Teacher 9 said

> *"We do not have males engaged with females in discussions... if you'd like that's a cultural thing."*

This separation could affect collaboration and the exchange of ideas between male and female students.

Code 2: Gender Dynamics in Classroom Discussions

In masculine cultures like the Omani culture, males are generally expected to be more outspoken and assertive (Hofstede, 1986). This has the potential to overshadow female participation in class discussions. Higher male participation during discussions could be attributed to a perceived natural inclination to engage in debates or discussions. This could reflect cultural or societal expectations for males to be more vocal in group settings. Teacher 1 said

> *"Male students interact more during class discussions... maybe because their nature they always like to discuss."*

Moreover, Teacher 1 contrasted males' tendency to discuss with the behavior of females, who are perceived to work more independently. They have a belief that females may not engage as much in discussions but prefer individual learning. They reported

> *"Do you know maybe because of their nature they always like to discuss. Females who like to receive are doing by themselves…"*

This reflects a potential stereotype, where males are seen as more active and females more passive in classroom dynamics, which may influence teachers' expectations and interactions with students.

On the other hand, most teachers noticed the opposite trend, where female students were more engaged in the classroom than male students. Teacher 2 said,

> *“Female students tend to be more interactive and engaged than male students.”*

Teacher 4 suggested that the learning environment might actively encourage female students to participate more, potentially as a way to counterbalance any existing cultural expectations for them to remain passive. They said

> *“Females are more encouraged to interact than males.”*

This encouragement could be a response to traditional gender norms, with teachers aiming to encourage female students to engage more in discussions and class activities.

Teacher 5 supported the view that female students are more active in classroom interactions than males. They said

> *“Female students' interactions are more than those of male students...”*

This could signal a shift in gender dynamics within the classroom, where female students are taking a more prominent role in participating and engaging with the material.

Teacher 5 also indicated that male students may exhibit shyness in interactions compared to female students, who are described as taking a more dominant role in the classroom. This contrasts the stereotype that male students are always more active participants. They said

> *“I think they may be more shy than female students to interact.”*

and

> *“In most of our classes, the strength is from female students. So definitely the female students interaction is more than male interaction.”*

These insights highlight the complexity of gender-based interaction patterns, where males may not always dominate discussions and may require more encouragement to participate.

Code 3: Academic Performance and Gender Engagement

The teachers' observations also extended to academic performance and gender engagement. Teacher 7 expressed a belief that female students may excel in academic tasks due to their focus and diligence, potentially placing them at an advantage over male students in certain classroom activities. They reported,

> *"Females are performing well because they focus more on their work."*

This observation supports the idea that female students may be more disciplined and dedicated to their studies, which might contribute to higher participation and engagement in class.

Moreover, Teacher 8, suggested that while female students are naturally more engaged, male students may require more external motivation or support to participate fully in classroom activities. They reported,

> *"Male students need more encouragement to engage...females tend to be more engaged naturally."*

This observation indicates that teachers may need to adopt different strategies to encourage male and female participation, with males potentially needing more guidance to engage in discussions.

Teacher 8 also highlighted a difference in behavior during discussions, with female students being described as more assertive in defending their viewpoints, while male students may be more open to changing their positions. They reported,

> *"Female students can be more stubborn in defending their answers during discussions, while male students are more flexible."*

This observation suggests that female students may exhibit more confidence in their answers, perhaps reflecting a growing sense of empowerment in academic settings. In contrast, male students may be more willing to adapt or admit during debates.

Teacher 8 also suggested that female students are more comfortable and proactive in small group settings, while male students may need additional encouragement to participate fully. They said

> *"Female students engage better in small groups while males require more direct prompting."*

Overall, teachers' observations highlighted the complexity of gender-based interaction patterns in their classrooms, challenging the traditional stereotypes that male students are more outspoken and assertive. These observations

suggest a potential shift in gender dynamics within educational settings and require further investigation.

6.1.4 Theme 4: Culture and Student-Teacher Interaction

Another theme, “Culture and Student-Teacher Interaction,” emerged from teachers’ interviews. This theme highlights the complex dynamics that govern the relationships between students and teachers within educational contexts. This section presents the findings related to this theme, particularly the code of formal student behaviour, which was identified through the coding of interviews responses.

Code 1: Formal Student Behaviour

Teacher 5 pointed to the formal behaviour observed in many students, who are less likely to express emotions or engage in more informal interactions with their teachers. Only a few students break from this norm by cracking jokes or displaying excitement. They reported

> *“I don't see much smiling faces... some students are very excited exceptional... they crack jokes and all but not many, very few cases.”*

This formal behaviour of students could be influenced by cultural expectations that emphasise respect and formality in academic settings. This formality may create a more reserved classroom environment where students are less inclined to engage in casual interactions with their instructors. Therefore, understanding this cultural behaviour is crucial for effective cross-cultural teaching and learning interactions (Hofstede, 1986).

6.1.5 Theme 5: Teachers’ Perspectives on Peer Instruction

The theme “Teachers’ Perspectives on Peer Instruction” emerged from a comprehensive analysis of qualitative data gathered from teachers’ interviews. The results highlight the benefits and challenges associated with implementing Peer Instruction in the classroom, reflecting a significant shift in pedagogical practices. The findings are categorised into ten distinct codes, each representing a critical aspect of teachers’ perspectives on PI.

Code 1: Increased Student Engagement

One of the primary benefits of active learning, as noted by Teacher 3, is the interactive nature it fosters between instructors and students. They state,

> *"It's interactive between me and the students... instead of just the student listening."*

This remark underscored the shift from passive reception to active engagement, where students are participants in their learning process, not just listeners.

Teacher 8 supported this perspective, noting that

> *"I see students are fully engaged and articulate. I see the male students are really more engaged than before."*

This suggests that active learning, including peer instruction, not only engages students but also reaches specific demographics that may traditionally participate less, enhancing the inclusivity and effectiveness of instruction.

Teacher 8 also highlighted an essential component of active learning by stating,

> *"Peer instruction allows students to discuss and defend their reasoning, not just passively listen."*

This indicates that active learning strategies like peer instruction encourage students to articulate and justify their ideas.

An additional advantage mentioned by Teacher 8 is that active learning

> *"breaks the monotony of the lecture."*

This observation reflects how the introduction of activities like peer instruction refreshes the teaching dynamic. The same teacher notes,

> *"If you introduce peer instruction during the lecture, I really find it like it breaks the borders,"*

pointing to the potential of active learning to create a more open and engaging learning atmosphere where students feel more at ease to contribute.

The benefits of active learning include a fundamental shift away from passive educational experiences. Teacher 5 stated,

> *"The biggest benefit is to make the class active. Otherwise, it is like passive teaching."*

This sentiment is echoed by Teacher 4, who remarked,

> *"Students stopped being bored out of their mind and about to sleep in class. That's the biggest and the single most important benefit is student engagement."*

Overall, the teachers acknowledged that PI significantly increased student engagement by shifting the learning process from passive listening to active participation. Students become more involved in discussions, ask more questions, and engage with the material in a meaningful way.

Code 2: Improving Understanding

Teachers noted that PI enhances students' understanding by encouraging collaboration and discussion. Students benefit from explaining concepts to each other and gain insights from their peers' perspectives. Several teachers reported,

> *"PI questions help them more in understanding the subject." (Teacher 2)*
>
> *"Peer instruction is very good... it helps us control the level of understanding." (Teacher 7)*
>
> *"Because they understand from each other much faster, because they know the level of the knowledge they can share together is easier than us." (Teacher 1)*

Code 3: Building Student Confidence

Some teachers highlighted how Peer Instruction (PI) aids students in building confidence in their knowledge. By engaging actively with peers and instructors, students feel more assured about their understanding of the material. Teacher 2 noted,

> *"Many students lack confidence in their knowledge, and active learning helps them overcome the confidence problem."*

and

> *"Active learning helps them to overcome the confidence problem."*

Code 4: Direct Feedback

One of the key benefits of PI is the ability to gather direct and immediate feedback on student understanding. Teachers mentioned that this feedback helps them adjust their teaching strategies and address any areas where students are struggling. Several teachers reported,

> *"Peer instruction... giving me direct feedback about the student understanding for a certain topic." (Teacher 3)*
>
> *"PI helps in getting immediate feedback and allows adjustments." (Teacher 7)*

> *“From my interaction with the students. I see them, you know, giving me very positive feedback about their experience.” (Teacher 8)*

Code 5: Passive Learning Background

Students are accustomed to traditional, passive learning environments where they receive information without much interaction or critical engagement. The shift from passive to active learning represents a cultural and pedagogical transformation and is challenging for students. Teacher 7 said:

> *“The transition is difficult because students are used to passive learning.”*

And Teacher 3 said:

> *“Their first experience with active learning in physics... they were not used to engaging before.”*

Code 6: Challenges in Self-Directed Learning

Self-directed learning is a critical component of active learning, but it presents challenges for students, who are not used to taking responsibility for their own learning in school education. Students often struggle when they are expected to learn independently, as it contrasts with the more structured and guided learning experiences they have previously encountered in school education.

> *“They stumble or have issues when they are expected to self-learn.” (Teacher 6)*

> *“So that impacts them like they expect the same kind of thing in the university level where we expect some kind of self-learning.” (Teacher 6)*

Code 7: Cultural Confidence Barriers

Some teachers noticed that students often face confidence barriers when transitioning to active learning, particularly if they are not accustomed to sharing ideas or participating in discussions. This lack of confidence can stem from both cultural and educational backgrounds that have not focused on open discussions.

> *“Many students come to us not that confident... it takes a bit of time for the students to get used to it.” (Teacher 9)*

Code 8: Focus on Grades

Another important aspect that teachers mentioned is that students mainly focus on achieving high grades, which is their primary motivation for engaging with the material. Sometimes, this focus on grades overshadows the goal of understanding the subject.

> *"They focus on grades and understanding, but they say, 'Give me marks.' The issue is that they are looking for the marks." (Teacher 3)*
>
> *"Their response was not 'I will not understand the lecture.' Their response was 'Am I going to get the marks?" (Teacher 2)*
>
> *"Students focus more on grades than understanding." (Teacher 3)*

Code 9: Adapting to Active Learning

Teachers acknowledge that adapting to active learning requires time and consistent encouragement. Students gradually become more comfortable with discussing and collaborating, particularly when using PI techniques, which allow them to engage with their peers in a structured format.

> *"Students need time to get used to it... encouraging them to get out, or try and do it." (Teacher 2)*
>
> *"Culturally, students are used to passive learning, so they need time and encouragement to adapt to active learning." (Teacher 2)*
>
> *"In school, they are more pampered... everything is spoon-fed, and it takes time to bring them to this mode of learning." (Teacher 6)*
>
> *"They will see this PI question as a chance to discuss with their partners, and after a while, they are used to it." (Teacher 2)*

Code 10: Combining Teaching Methods

Many instructors advocate a blended approach, incorporating traditional methods alongside PI and other active learning techniques. This balance allows for varied cognitive engagement, acknowledging the strengths of both traditional and active methods in fostering comprehension and retention.

> *"For me, I would use, for example, the traditional way with some other active learning effects with the PI, like a combination of both." (Teacher 1)*
>
> *"It's very good in my opinion, but without ignoring the traditional way. Like if there's a combination." (Teacher 1)*
>
> *"There's no harm in having this hybrid system. After all, you want to train the brain in different ways using different approaches." (Teacher 2)*

> *“I believe in a 60-40 blend between peer instruction and traditional teaching.” (Teacher 6)*

Some instructors applied a wide range of teaching strategies, including inquiry-based learning, labs, and hands-on methods, in addition to PI. This diversity in approaches is seen as a way to support different learning styles and make learning more comprehensive.

> *“I do use PI, but I also use interactive sessions. I do use study methods. I do use inquiry-based learning to labs and electronics for example.” (Teacher 4)*

Overall, the results of this theme reveal teachers' appreciation for the benefits of Peer Instruction, such as increased student engagement, improved understanding, and enhanced confidence. However, they also highlight challenges associated with transitioning from passive to active learning environments, emphasising the need for continuous support and adaptation in pedagogical practices. The findings suggest that a balanced approach combining traditional and active learning methods could be the most effective strategy for fostering an inclusive and engaging learning environment.

6.1.6 Theme 6: Teachers’ Perspectives on Pre-Reading

One of the main requirements of Peer Instruction is that students must come to the class prepared by doing a pre-reading assignment. Therefore, an important theme arising from the interviews focused on teachers’ perspectives regarding the pre-reading assignments. The analysis of teachers’ perspectives on pre-reading revealed some benefits, challenges, and cultural factors influencing students' engagement with pre-reading assignments in the context of Peer Instruction. The data was categorised into ten distinct codes, each highlighting different dimensions of the pre-reading experience from the teachers' viewpoints.

Code 1: Pre-Reading Benefits

Teachers in general acknowledged the benefits of pre-reading, particularly in terms of preparing students for lectures, fostering critical thinking, and encouraging long-term learning habits.

> *“We assign reading and the students must answer a quiz before the lecture, which helps with their preparation.” (Teacher 6)*

> *“I think it is helping in that sense... So, I think I am very much for reading the textbook before the lecture.” (Teacher 9)*

“We want them to be long-term learners, and reading helps develop critical thinking.” (Teacher 2)

Code 2: Pre-Reading Resistance

Teachers also noticed that students exhibit resistance to pre-reading, which is often due to unfamiliarity with the method, lack of motivation, and the added workload.

“Students often resist at first because they are not used to the pre-reading style.” (Teacher 8)

“Students perceive pre-reading as an additional burden.” (Teacher 4)

Many students opt for finding shortcuts, such as sharing answers to the pre-reading assignment, which indicates a lack of motivation and engagement.

“You also get a whole bunch of students sharing the answers online, which again tells me that they are not motivated to do the pre-reading.” (Teacher 4)

Code 3: Cultural Habits of Passivity

Cultural norms around passive learning influence students’ expectations in the classroom. Many students come from educational backgrounds where active preparation was not emphasised, making pre-reading a new concept for them.

“Culturally, students are used to being listeners, not actively preparing.” (Teacher 7)

“They didn’t have to read before coming to class, so this is new to them. They are not used to doing pre-reading.” (Teacher 5)

Code 4: Pre-Reading Workload Challenge

Some teachers highlighted that students often face challenges balancing pre-reading with their other course responsibilities. When students are enrolled in multiple classes, it becomes difficult to allocate time for pre-reading, leading to increased stress and a sense of burden.

“The pre-reading is a very good idea if you’re talking about just one course... but the reality is they are taking more than four courses.” (Teacher 1)

“It’s difficult for them to prepare for every single course. Thinking about applying. It could be applied to every single course as well.” (Teacher 1)

> *“We need to bear in mind that the students only have this one course, they usually have four or five courses in a single semester.” (Teacher 4)*
>
> *“Pre-reading would work better with fewer courses during the semester, but in reality, it's not practical because of the heavy load.” (Teacher 1)*

Code 5: Forcing Pre-Reading is Ineffective

Some teachers felt that "forcing" pre-reading assignments does not lead to effective learning or student engagement. Students may view pre-reading as a burdensome requirement rather than a helpful tool, leading them to not engage in this task.

> *“I found that forcing pre-reading down the throat of students has no effect.” (Teacher 4)*
>
> *“I stopped shoving it down the throat of students.” (Teacher 4)*

Code 6: Pre-Reading Versus Videos

Teachers acknowledge that some students prefer videos over reading the textbook because videos are perceived as more accessible and engaging. Videos offer an alternative way to consume information, which can sometimes be easier to process than reading texts.

> *“Because they can watch videos anytime they are interested to see and hear instead of just reading papers.” (Teacher 1)*
>
> *“Students sometimes resist doing the reading because they prefer watching videos... It’s easier for them.” (Teacher 2)*

The preference for videos over reading may suggest a shift in how modern students engage with information. Integrating multimedia resources alongside or in place of traditional pre-reading assignments could accommodate different learning styles and potentially increase student engagement.

> *“This is the generation that used to get their information in 30 second clips on you know, Tik Tok and Snapchat.” (Teacher 4)*

Code 7: Pre-Reading Language Difficulty

Teachers noticed that students frequently find pre-reading challenging due to the complexity of English, particularly in scientific textbooks. This difficulty can hinder their understanding of the material, making it harder for them to engage effectively in class discussions.

“Students keep saying it’s very difficult for me... because it is difficult English.” (Teacher 4)

“Many of them said they have difficulty in reading the textbook in English.” (Teacher 1)

“Yes, the book that we have definitely the English is steep for them.” (Teacher 9)

Code 8: English Proficiency Required

Some teachers believed that scientific texts are relatively accessible and that the primary challenge lies in students’ initial unfamiliarity with technical language and general English proficiency. The language in scientific textbooks is perceived as structured and repetitive, which may aid in comprehension over time.

“They have a minimum level of English knowledge to understand anyways.” (Teacher 6)

“Scientific textbooks are straightforward; English is not the issue.” (Teacher 7)

“Scientific language is simple and direct; it’s good practice for them.” (Teacher 7)

Code 9: Translation Issues

Some teachers acknowledged that literal translation of English terminology into Arabic can lead to misunderstandings, as certain scientific terms or phrases may not translate directly or retain the same meaning in different cultural contexts.

“Textbooks are written in the US...many times these words...are interpreted literally word to word by Arabic speakers and it gives a totally different meaning.” (Teacher 8)

Code 10: Improvement in English Reading

Teachers believed that regular exposure to English reading through pre-reading assignments improves students' language skills over time. This gradual improvement not only benefits their comprehension of scientific texts but also builds overall language proficiency.

“With time, they admitted that reading is becoming better, and specifically reading English is much better.” (Teacher 8)

“Pre-reading quizzes are a chance for them to practice English... they may not be reading much otherwise. Pre-reading helps improve their reading skill as well as English...” (Teacher 5)

> *“Some students actually told me that the reading is easier than when they had it in Physics 1 because they've gotten used to it.”*
>
> *(Teacher 9)*

Overall, the results of this theme highlight the teachers' perspectives on pre-reading. While the benefits of pre-reading are acknowledged, significant resistance, language challenges and cultural habits must be addressed to enhance student engagement and learning outcomes.

6.1.7 Theme 7: Teachers’ Perspectives on Context-Rich Problems

This theme presents the findings derived from analysing teachers' perspectives on context-rich problems in physics teaching. The analysis revealed three principal codes that present the teachers’ views: Preference for Context-Rich Problems, Cultural Relevance in Context-Rich Problems, and Language Barriers in Context-Rich Problems. These codes are discussed below.

Code 1: Preference for Context-Rich Problems

Some teachers prefer context-rich problems, which present students with real-life scenarios and require them to apply multiple concepts simultaneously. These problems are often viewed as more effective in developing problem-solving skills and critical thinking compared to traditional problems.

> *“In the tutorials... we did not have what you call traditional problem-solving tutorials, we had context-rich problems.” (Teacher 9)*
>
> *“I prefer using context-rich problems rather than simple step-by-step problems.” (Teacher 8)*

Code 2: Cultural Relevance in Context-Rich Problems

Some teachers suggested that students relate better to problems that reflect their cultural context, making the abstract nature of physics more evident. Using familiar names and scenarios helps students see the relevance of physics in their daily lives, enhancing their motivation and engagement.

> *“These context-rich problems must be adapted to the environment and the culture, for the students to be able to see physics is related to my real life.” (Teacher 8)*
>
> *“We use Arabic names... we try hard to use names of villages and cities in Oman so that it's related more to what students experience in their own life.” (Teacher 9)*

Code 3: Language Barriers in Context-Rich Problems

Teachers admitted that the language used in context-rich problems poses a significant challenge. When presented in English, students may struggle to fully engage with the material because their focus shifts to understanding the language rather than the physics concepts. Long descriptive texts may be overwhelming, especially if students have limited English proficiency.

> *“The problems are like a story. Reading a text in English is boring for the students... They need something in a capsule form.” (Teacher 5)*
>
> *“We can see the pain in their faces at times with some of the problems because of the English... they have to analyze it in English, and that's not an easy thing.” (Teacher 9)*
>
> *“A good portion of time for the context-rich tutorials goes to understanding the English.” (Teacher 9)*

Overall, the results of this theme emphasise the importance of context-rich problems in physics education, as perceived by teachers. Teachers prefer these problems because they can enhance critical thinking and problem-solving skills, while cultural relevance plays an important role in student engagement. However, language barriers present significant challenges that must be addressed to maximize the effectiveness of context-rich problems.

6.1.8 Theme 8: Teachers’ Perspectives on Traditional Problem Solving

The analysis of teachers' perspectives on traditional problem-solving methods revealed diverse viewpoints and experiences. The theme “Teachers’ Perspectives on Traditional Problem Solving,” includes five different codes that illustrate the nature of traditional problem-solving in educational settings.

Code 1: Benefits of Traditional Problem Solving

The traditional problem-solving method was valued by some teachers for helping students build a structured approach to understanding logic, equations, and core concepts.

> *“Traditional problems help students process information with appropriate equations.” (Teacher 5)*

> *“This method offers a clear vision and reinforces key concepts.” (Teacher 7)*

This method was seen as essential for developing the flexibility needed to solve complex, real-world problems with context-rich scenarios.

> *“Traditional problem solving helps train the brain to be more flexible when it comes to solving real-life problems.” (Teacher 2)*

Code 2: Drawbacks of Traditional Problem Solving

Other teachers expressed concerns that traditional problem-solving can become ineffective if students are only passive observers. When instructors solve problems without student participation, there’s a risk that students will fail to retain the information or develop essential skills.

> *“If the students are not doing it themselves, then there is no retention whatsoever.” (Teacher 4)*
>
> *“It is a useless activity if the instructor is just solving the problem for them.” (Teacher 6)*
>
> *“They will understand it, but they will forget and no skills are added.” (Teacher 6)*

Code 3: Attitudes Toward Traditional Problem Solving

Teachers had mixed attitudes and feelings about traditional problem-solving. Some of them saw it as an outdated method that fails to engage students.

> *“I don’t see myself going and solving a problem from A to Z on the board anymore.” (Teacher 8)*
>
> *“Traditional problem-solving by itself is not the greatest thing.” (Teacher 9)*

On the other hand, others believe that traditional problem-solving remains an essential part of instruction that cannot be ignored.

> *“I feel it's very important. Like we cannot ignore like solving problems in the traditional way.” (Teacher 1)*
>
> *“It's a good way to do it for them because at a certain point, they need to understand the steps to solve the problem.” (Teacher 3)*

Code 4: Engaging Students During Problem Solving

Instructors, who supported traditional problem solving, emphasized the need for engagement by encouraging students to participate actively, either by attempting problems first or by answering instructors’ questions at each step. This

engagement is critical for ensuring that students understand the problem-solving process.

> *“First, they have to try, and then I solve it for them.” (Teacher 6)*
>
> *“You can ask questions before you go to the next step.” (Teacher 7)*
>
> *“Just make it interactive... you can stop and ask volunteers to continue solving on the board.” (Teacher 7)*

Code 5: Balance Between Traditional and Context-Rich Problems

Many instructors believed that while context-rich problems are valuable, traditional problem-solving should not be discarded. A balanced approach that combines both types of problems is seen as ideal, providing students with foundational skills through structured learning as well as opportunities to apply these skills in more complex situations presented in context-rich problems.

> *“Traditional and context-rich problems are entangled; both are important.” (Teacher 5)*
>
> *“We should not ignore traditional problem-solving... balance has to be found.” (Teacher 1)*

The findings of this theme highlight both the perceived benefits and drawbacks of traditional problem-solving and teachers' attitudes toward its implementation in the classroom. Furthermore, the necessity of student engagement and the importance of balancing traditional and context-rich problems emerged as critical components of effective teaching practices.

6.2 Interviews with Students:

This section presents the findings from the students’ interviews. The focus is on their experiences with peer instruction and interactions with peers and teachers.

Students were selected and recruited voluntarily. They were asked in the CLASS survey if they were willing to be interviewed by the researcher. This method resulted in recruiting students from various majors and experiences with Peer Instruction. Detailed information about the interviewed students is listed in Table 6-1. All interviews were conducted in Arabic according to students’ preferences, except for the second interview. An official translator translated one of the interviews into English. The supervisors coded this interview in English, and the researcher coded it in Arabic. The resulting codes from the three of us were

discussed and agreed upon. Accordingly, the researcher coded the rest of the interviews.

Students' perceptions of the influence of language and culture on their ability to engage in peer-to-peer interactions, share ideas, and collaborate effectively with classmates will be discussed.

Moreover, students' perspectives on the role of teachers in facilitating peer instruction and providing support and feedback to enhance peer-to-peer learning experiences will be explored.

Student No.	Gender	Major	Year	Teaching Method
1	F	Education	3	Face to Face PI
2	F	Science	3	Face to Face PI
3	M	Agriculture	3	Face to Face PI
4	M	Engineering	3	Traditional
5	M	Education	2	Online PI
6	F	Science	3	Online PI
7	M	Engineering	2	Traditional
8	F	Science	4	Face to Face PI
9	M	Engineering	4	Traditional
10	F	Science	2	Online PI
11	F	Science	2	Online PI
12	M	Engineering	2	Traditional
13	F	Science	3	Online PI
14	M	Engineering	2	Traditional
15	M	Engineering	2	Traditional
16	F	Engineering	2	Traditional
17	M	Science	2	Face to Face PI
18	M	Engineering	2	Traditional
19	M	Science	2	Face to Face PI
20	M	Engineering	2	Traditional
21	F	Engineering	2	Traditional

Table 6-1 Detailed information about the interviewed students

6.2.1 Theme 1: Language and Student-Student Interaction

The theme of “Language and Student-Student Interaction” emerged as a significant area of exploration within the context of academic discussions among students. The analysis of student responses revealed a relationship between language use, comfort levels, and the dynamics of peer interactions. The findings are categorised into several codes, each reflecting the ways language influences student engagement and comprehension in a bilingual learning environment. These codes are discussed below.

Code 1: Language in Discussion

Students expressed a variety of perspectives on their language use during discussions.

Some students expressed challenges with English, stating that it sometimes creates anxiety. Student 12 explained,

> *“In English, I get very nervous; for example, if I try to write a sentence on paper, I can write it correctly, but if I try to say it, everything comes out wrong”*

This discomfort leads them to favour Arabic, where they feel more confident.

Moreover, many students indicated a preference for using Arabic in discussions due to its effectiveness for communication among peers. For example, Student 1 noted,

> *“I use Arabic because it makes it easier for me to communicate with my classmates… I have more freedom to explain in Arabic, give examples, and speak in colloquial Arabic. So, I definitely prefer Arabic.”.*

This preference was repeated by Student 10, who stated,

> *“I feel like Arabic is better because we studied it in English, so we want to teach each other in Arabic.”*

Student 8 also stated

> *“It helps to convey our understanding faster because in Arabic, we understand better; for example, even the expressions, even the tone of voice is clearer in Arabic.”*

While they preferred to communicate in Arabic, many students described a blending of the two languages during discussions. Specifically, they acknowledged the necessity of using English for technical physics terms. Student 17 pointed out that they often

> *“We use English technical terms; we say how we derived this ‘acceleration’, how we derived this ‘velocity’...while the conversation is all in Arabic”*

and student 13 mentioned,

> *“We talk to each other in Arabic, but we use English for the terms”.*

This indicates comfort with switching between languages as needed, particularly for technical terms.

This blend of languages helps students navigate academic discussions more effectively. Student 19 mentioned,

> *“I feel that discussing in Arabic and English helps me understand quickly”.*

A recurring belief was that understanding the content of the course is more important than the language used. Student 17 emphasized,

> *“The important thing is to understand it; that’s how I feel about physics. The most important thing is understanding, not the language”*

This highlights the students' focus on comprehension rather than strict adherence to one language.

The students also noted that their background influences their language use. Student 16 remarked that the discussion was in Arabic

> *“because we are all Omani students”*

Student 4 highlighted a simillar viewpoint stating,

> *“We all don’t know how to speak English. Why we go the difficult route? Let’s go in Arabic, right?”*

Student 3 also emphasized this cultural behavior by stating,

> *“The language of communication between us as students is Arabic. I do not remember any student, who used English in group discussion.”*

And student 5 went further by conveying a sense of frustration towards a peer who consistently used English, which was considered a strange behavior, noting,

> *“There was one person I don’t know what his intention was; he always talked to us in English”*

Therefore, even if a student does not mind discussing in English, he will follow the most common behavior. Student 7 stated,

> *“I don’t really mind either, it depends on how my colleague understands me. If my colleague understands me better in English, I*

speak in English; if my colleague understands more in Arabic, I speak in Arabic, and most discussions in the university are in Arabic."

This suggests a cultural connection to language choice in academic settings.

Overall, the students demonstrate a practical approach to language use in discussions, valuing effective communication and understanding over strict adherence to one language, while also adapting to the requirements of their academic context.

6.2.2 Theme 2: Language and Student-Teacher Interaction

The theme of "Language and Student-Student Interaction" emerged as a significant area of exploration within the context of academic discussions among students. The analysis of student responses revealed a relationship between language use, comfort levels, and the dynamics of peer interactions. The findings are categorised into several key codes, each reflecting how language influences student engagement and comprehension in a learning environment. These codes are discussed below.

Code 1: English Language Barrier

Students expressed various challenges regarding the English language barrier when interacting with their non-Arabic-speaking teachers, and many indicated a preference for instructors who understand Arabic.

Student 12 highlighted how the pressure of speaking English can affect his communication.

"English makes me a bit anxious when speaking."

Moreover, student 18 reflected a common concern among students about their ability to communicate effectively in English.

"Sometimes I cannot express the English language correctly. And explain it to him."

On the other hand, student 15 indicated a gap between conversational English and academic language, making it difficult to seek help.

"I struggled a lot. Even in regular terms, I did not know. It is not that I do not know how to speak English, but the terms are different from conversation, and I cannot ask the teacher."

Student 6 emphasises the importance of language familiarity in effective learning.

> *"Because Arabic is my native language, when information reaches me, it is the style and words that will explain my situation, unlike English."*

Student 9 also pointed to a significant disconnect between lecture content and student comprehension due to language barriers.

> *"For example, a large group was in the physics course this semester. I sat with them, and most understood only the tutorial; the things the doctor said in the lecture were not understood by many."*

Some students demonstrated a sense of helplessness in the face of language barriers, leading them to seek information elsewhere. Student 19 mentioned,

> *"So I just stay quiet and look for external sources? There is no other way, you know?"*

To help overcome the language barrier, some students relied on peers for clarification within group settings.

> *"I resort to my classmates?" (Student 11)*
>
> *"I ask for help from classmates?" (Student 16)*
>
> *"If I have girls in the group, I let them speak on my behalf."*
>
> *(Student 21)*
>
> *"The tutorial is group work, so if I cannot convey the idea to him, my colleague will convey it to him." (Student 18)*

Another approach to overcoming language barriers is communicating by writing and sending emails, as a more comfortable medium for communication. Student 18 pointed,

> ***"****I tell him I will send you my question via email. It provides another way of communication. Alternatively, should I come to your office?"*

and

> *"In writing, I translate and organise myself better."*

Other students have coping strategies, such as using drawings as a form of expression when language fails. Student 14 noted,

> *"I try, for example, to draw the question?"*

This highlights the students' need for alternative methods to convey their questions and the desire for clarity in their explanations.

In summary, students expressed some barriers to communicating in English with their teachers. To help overcome these barriers, they often resort to their peers' support, utilise alternative communication strategies, and struggle with academic terminology in English, complicating their learning experience.

Code 2: Arabic vs. Non-Arabic Teachers

Students expressed their preferences and experiences regarding Arabic-speaking versus non-Arabic-speaking teachers.

Many students feel that having a teacher who knows Arabic significantly aids in their understanding. They believe that Arabic-speaking instructors can clarify concepts and terms, making learning more accessible.

> *"I prefer he knows Arabic. Because if there is something I did not understand or something that needs clarification in Arabic, he explains more to me." (Student 10)*

Students also mentioned that an Arabic-speaking teacher can explain difficult terms and concepts in a way that is more relatable, helping students connect what they learn to their previous knowledge from high school.

> *"I prefer he knows Arabic because it helps us connect the information we already have more."(Student 11)*

The ability to use Arabic becomes crucial when students encounter new or difficult terminology, as it allows for immediate clarification.

> *"It does not really matter but if he knows Arabic, if we do not understand a word, he can explain it to us." (Student 12)*

Several students expressed a preference for Arabic-speaking instructors due to the comfort and clarity they provide in the classroom. They feel less confused and can engage more effectively in discussions.

> *"It is better if he knows a little Arabic to explain to us in Arabic, making it easier for us to understand what the doctor says." (Student 17)*

Some students are open to teachers who use a mix of the two languages. They appreciate being able to hear explanations in both Arabic and English, believing it helps bridge understanding, especially in complex subjects.

> *“He can explain everything in English, but for example, if we ask what a term means, he tries to give us the meaning in English, and if we still didn't understand it, he says the word in Arabic.” (Student 18)*

While many students prefer an Arabic teacher, some are indifferent or adaptable, indicating that they can still learn effectively from non-Arabic-speaking teachers if the teaching method is appropriate.

> *“If the university is in English, I have no issue whether a doctor teaches us in Arabic or English.” (Student 9)*

The cultural context of the students plays a role in their preferences. These students have primarily studied in Arabic throughout their educational experience and often find it difficult to transition fully to English instruction.

> *“Honestly, I prefer that he speaks Arabic because not all the students who entered Sultan Qaboos University understand English.”*
>
> *(Student 7)*

In summary, students generally favour Arabic-speaking teachers for their ability to clarify concepts and facilitate communication. However, there is an acknowledgement that effective teaching can occur in both languages, depending on the teacher's methods and the subject matter. The comfort and clarity provided by Arabic instruction play a significant role in students’ learning experiences.

6.2.3 Theme 3: Culture and Student-Student Interactions

This section presents the findings from the thematic analysis of student interviews regarding culture and student-student interactions within the peer instruction and cooperative group discussions. Four primary codes emerged from the data: Group vs. Individual Work, Confidence in Participation, Changing Groups, and Role in Discussions. Each code reflects students’ experiences contributing to their interactions and learning outcomes in group settings. These codes are discussed below.

Code 1: Group vs. Individual Work

Students expressed varying preferences regarding group versus individual work.

Many students preferred working alone, citing reasons such as avoiding confusion, feeling embarrassed in group settings, and finding individual study to be more effective.

> *"Maybe alone so I do not get confused?" (Student 10)*
>
> *"In fact, I like to solve them alone." (Student 1)*
>
> *"I haven't tried solving with my classmates; I prefer to do it alone."(Student 11)*
>
> *"Honestly, I prefer to solve alone." (Student 17)*

Some students expressed concerns about group work leading to distractions or ineffective collaboration, indicating that working with peers can sometimes devolve into socializing rather than studying.

> *"I have not studied with other people because if I sat with one of my friends, it just turns into a general chat." (Student 12)*
>
> *"I prefer to solve by myself because if I sit with others, I feel like I am wasting time." (Student 13)*

Despite the preference for individual work, some students recognise the benefits of group discussions for enhancing understanding and reinforcing knowledge. They see value in discussing ideas with peers to solidify their learning.

> *"I do not deny the effectiveness of working in groups as well" (Student 1)*
>
> *"I love discussion because it solves the questions in my mind and addresses the things that are missing in my mind." (Student 7)*
>
> *"Discussion is nice, listening is good too, but I prefer the discussion..." (Student 15)*

Some students prefer a combination of both approaches, indicating that while they value individual study, they also appreciate the opportunity to collaborate and discuss with others when needed.

> *"I prefer to discuss so that the information sticks more, but I do not have a problem whether alone or with someone." (Student 10)*

In summary, students exhibited a strong inclination toward individual work, often citing concerns about the distractions of group settings. However, they also acknowledged the advantages of group discussions for deeper understanding and knowledge reinforcement, suggesting a nuanced view that values both approaches depending on the context.

Code 2: Confidence in Participation

Many students expressed feelings of shyness that influenced their confidence to participate. For instance, Student 1, who is a female student, stated:

> *"I feel embarrassed, so I prefer to solve the problems alone."*

Student 10 adds a lighthearted note about her shyness:

> *"I prefer to discuss, but I feel shy, haha."*

Some students indicated that uncertainty about their answers affected their willingness to engage. For example, Student 2 mentions:

> *"Because sometimes I do not feel confident in my answer... so I prefer to sit and just watch what will happen sometimes."*

Engaging with peers can enhance confidence for some students. Student 3 points out:

> *"So, that makes me sure about the answers and about the ideas of that question."*

Several students expressed strong confidence in participating in discussions. Student 12 stated:

> *"Yes, yes, I have the confidence to participate in discussions."*

Student 15 reinforced this sentiment:

> *"No, thank God I have confidence. Even if I was wrong, what will happen? We are here to participate."*

Student 19 illustrated that understanding the material boosts confidence:

> *"If there is something I do not understand at all, I can ask my colleague."*

Conversely, Student 19 also shared moments of hesitation:

> *"So sometimes when there is no reason or I do not understand, or I do not know where I am, I just stay quiet."*

Language proficiency emerged as a significant factor affecting confidence. Student 12 discussed this impact:

> *"Is it because of the language. Honestly, I am not good at English."*

Overall, the students expressed a range of sentiments concerning their confidence in participation. While shyness and uncertainty often lead them to prefer individual work, many recognised the benefits of discussion for solidifying their understanding and boosting their confidence. Contextual factors, such as familiarity with the material and language proficiency, significantly influence their confidence levels and willingness to engage actively in classroom discussions.

Code 3: Changing Groups

In cooperative group problem solving, the instructors change the group members every three weeks as mentioned in the Introduction chapter.

Some students considered changing groups as an opportunity to gain new perspectives and experiences.

> *"Yes, it is fine to change. It introduces me to new people and new ideas." (Student 20)*

While some appreciate the novelty that comes with changing groups, others believe it may not always yield better results.

> *"Change is good; it brings new ideas and things like that. But it's not always better." (Student 17)*

Other students expressed a preference for staying with the same group, indicating that it saves time and fosters better collaboration.

> *"I prefer to work with the same group. Even if we do not choose it at first, because every time there is a new group, it wastes time." (Student 19)*

Students noted that familiarity with group members can facilitate easier discussions and exchanges of ideas.

> *"We had ease in discussions and exchanging ideas, so I did not face any issues with changing the group because we know each other." (Student 16)*

Some students felt uncomfortable when they were placed in groups with members who did not contribute effectively.

> *"I am not comfortable at all because usually there are disruptive students who are not interested." (Student 18)*

Student 19 expressed frustration with not being able to understand the material during tutorials and how frequent group changes exacerbate the situation, making it harder to follow the content.

> *"It was generally very bad. I felt the issue was that I always went to the tutorial and did not understand, and I was not up to date with the chapter that I was supposed to be following in the tutorial. Or we finished part of it, but not the whole thing. Yes. Also, the doctor changes the students every time or changes the groups for each tutorial, which makes the situation worse."*

Some students indicate their willingness to adapt to new groups, understanding that it is a necessary part of the learning process.

> *"Yes, I feel that I accepted the situation. I did not feel it was unfair to myself; it is normal." (Student 18)*

In summary, students have diverse views on changing groups. While some welcome the opportunity to interact with new people and ideas, others prefer the stability and familiarity of working with the same group.

Code 4: Role in Discussions

In cooperative group problem-solving, instructors assign specific roles to group members, including manager, questioner, and recorder, as mentioned in the Introduction Chapter. These roles are shuffled every week. Students expressed various opinions and experiences concerning their participation and the dynamics within group work.

There was a variability in student engagement during discussions; some felt they contributed moderately.

> *"I do not think I am the type who is very active, and those who like to explain are kind of in the middle, neither too quiet nor too talkative" (Student 18)*

On the other hand, some students highlighted that they were more comfortable absorbing information rather than contributing actively during group discussions.

> *"I prefer to be a listener. I feel shy to offer an idea, and it might not be related, and it comes out wrong." (Student 5)*

Some students pointed out a lack of dedication from all group members to commit to the specified roles.

> *"No one committed. I keep seeing that no one is committed."*
>
> *(Student 15)*
>
> *"No one committed to the tasks, not even 1%."(Student 15)*

There was some level of adaptability and understanding within group dynamics, leading to the exchange of the members' roles.

> *"In the beginning of the semester, we committed to the role of each one here, but towards the end of the semester, it became normal that if one of them had difficulty with their role, they could exchange it with their colleague." (Student 16)*

Some students highlighted the spontaneous and collaborative nature of discussions, where some students take the role that suits their skills the most and do not stick to the specified roles.

> *"Whoever knows how to draw, for example, in the diagram we have, they will draw it." (Student 13)*
>
> *"Because everyone knows something, right? I knew something, so I had an idea in my mind. The guys did not know how to solve this question, so I wanted to draw the diagram. Of course, they did not know how to draw, so I drew it. It clarifies the picture for them more after drawing." (Student 13)*
>
> *"I prefer to write on paper so I can see and understand what I am doing and what is happening." (Student 18)*

There was a sense of confusion or lack of direction in distributing the roles to the group members during discussions. Student 17 commented,

> *"Honestly, it was random. There was never a clear structure; I feel it is unnecessary. Haha."*

Student 15 suggested that assigning roles should be established by the group members themselves by stating,

> *"I feel that the group should be the one that chooses who will be the recorder, who writes, who thinks, etc.,"*

Some students highlighted a perceived ineffectiveness of certain roles in group tasks such as the role of Questioner. Student 18 stated,

> *"Some tasks require commitment; for example, the recorder must record… but the role of the questioner was not significant… that was our shared responsibility to ask and reach the idea. I feel it is not supposed to be that one person is only responsible for the questions… the manager, I think, is useful; she gather the girls and bring the tools, and I felt that it was slightly beneficial. Haha."*

Student 19 expressed frustration with unclear or irrelevant tasks, leading them to disregard the assigned roles in the answer sheet and only focus on the essential details (e.g., writing names) and engaging with the material.

> *"No, not at all. In fact, when we see the roles on the paper, we are surprised, like, 'What is this?' We scratch it out, scratch it out and just write the names. Fine, that is it. We do not bother trying to understand these roles."*

Student 15 expressed an apparent dissatisfaction with the current approach to group work, declaring,

> *"I do not feel the method of assigning roles to group members is effective; on the contrary, it is a failure."*

This statement reflects a critical viewpoint on the pedagogical strategies employed, suggesting they might not facilitate productive collaboration or engagement.

Overall, students' interviews revealed a complex picture of student participation in discussions, marked by issues of commitment to specific roles, the effectiveness of roles, and varying degrees of confidence and engagement.

6.2.4 Theme 4: Culture and Student-Teacher Interactions

This theme presents the findings from the qualitative analysis conducted on student experiences regarding interactions with teachers in school and university settings and the impact of teacher gender on these interactions. The results are organised into two main codes: the differences in student-teacher interactions

between school and university environments and the influence of teacher gender on student perceptions and experiences. These codes are discussed below.

Code 1: School vs University Interaction

Students expressed various perspectives on interactions in school compared to university settings, highlighting key differences in communication, participation, and teacher-student relationships.

The transition to university settings, especially in large classes, often results in increased anxiety and stress for students, impacting their willingness to engage.

> *"The students coming from school have some stress because it was a large lecture filled with people they did not know." (Student 7)*

This stress made it harder for them to approach professors with questions.

> *"This scenario gave the student coming from school a kind of stress. If this takes part of your thinking, you might hesitate to ask the doctor about a particular point." (Student 7)*

Participation in university was perceived as less frequent and less interactive than the more engaging school environment.

> *"In university, the participation is not the same as in school; in school, the teachers would ask us a lot, unlike in university."(Student 1)*

The increase in student numbers in university classes makes it challenging to receive personalized attention from professors, leading to a sense of distance.

> *"In university, where the doctor has about 80 students or more, so it becomes a bit difficult." (Student 1)*

On the other hand, students noted that smaller class sizes in school facilitate better communication and understanding between teachers and students, which diminishes in university due to larger class sizes.

> *"I feel that the communication between the teacher and the student in school is a bit more than in university... Perhaps because the teacher in school teaches only about 23 students, so they are able to communicate with them." (Student 1)*

Moreover, students expressed that the lack of familiarity with professors in university courses hindered their ability to ask questions freely, affecting their learning experience.

> *“I feel that interaction in school is more... the doctor is not familiar with the students through many courses.” (Student 9)*

Students expressed a feeling of detachment from university professors, contrasting with the closer relationships formed with school teachers.

> *“I feel we were closer to the teacher at school than to the professors at the university. In university, you feel a bit distant...”(Student 13)*

Some students felt that university professors were unapproachable and not lenient. This lack of interaction made it harder for students to ask questions or clarify doubts, impacting their learning experience.

> *“They might think that the doctor is not lenient with them and that he doesn’t care. Honestly, some professors don’t care about the students; they just come to the lecture, deliver what they need, and leave. There are no discussions.”(Student 7)*

The transition to online learning in university reduced the number of students willing to participate, impacting overall engagement.

> *“In school... there was a lot of interaction. However, in university, since it was online, only about ten out of 100 or 120 students would interact.”(Student 12)*

The anonymity of larger classes in the university can lead to students feeling overlooked and less inclined to participate.

“If you don’t participate, no one sees you; no one cares.” (Student 18)

The mixed-gender along with larger class sizes also contribute to the challenges in interactions, making it harder for individual students to engage.

> *“There’s a mix between boys and girls; the large number of students in the big halls makes it difficult for someone to answer from above.” (Student 14)*

Many students recognized that only a few actively participated, while the majority remained passive, especially in larger lectures.

> *“You end up with only a small group, maybe three or four students... while the rest seem uninterested.” (Student 20)*

In the contrary, some students felt that, despite the larger class sizes, they found themselves more comfortable participating in university discussions.

"In university, students are more comfortable participating; their participation is more effective compared to school. In school, participation is restricted; they have to raise their hand and do many things." (Student 15)

In Summary, students highlighted significant differences in interactions at school versus university, including communication effectiveness, participation levels, and the nature of teacher-student relationships. These factors play a crucial role in shaping students' academic experiences and their comfort in engaging with their instructors.

Code 2: Gender of the Teacher

Students expressed a range of perspectives on the impact of teachers' gender on their educational experience.

Student 17 noted that their initial perception of the difference between male and female professors had changed as they interacted more with them:

> *"At first, I thought there would be a difference between a male and female professor, but as I tried to talk to professors more, I realised I did not feel that much difference."*

This indicates that while students may have expectations based on gender, personal experience can lead to nuanced views.

Student 18 expressed that the effectiveness of teaching is more about the individual teacher's personality rather than their gender:

> *"Honestly, it does not matter whether it is a male or female professor. Sometimes the male is better, and sometimes the female is better, depending on the teacher's personality."*

This perspective underscores the idea that teaching effectiveness transcends gender.

On the other hand, some students felt that female teachers have a better ability to convey information and provide explanations. For example, Student 14 stated:

> *"Of course. Female teachers are better. They have an easier way of explaining and providing information to the students. They do not have a problem if someone does not understand; they repeat more than once."*

This sentiment indicates a belief that female teachers may be more patient and willing to clarify information.

Moreover, student 21 shared that they might find it easier to communicate with female teachers:

> *"For me, as a female student, I might find it easier to relate when the teacher is a woman."*

This suggests that some students, especially females, feel more comfortable discussing personal issues or seeking help from female teachers.

Interestingly, student 15 highlighted a perceived bias, noting that female lecturers may treat male students better than female students:

> *"If the lecturer is female, she treats male students better than female students... I asked several university students, and they said the same thing."*

This suggests that some students observe gender-based differences in teacher-student interactions, which could influence their learning experience.

Student 16 emphasised the importance of learning from both male and female professors for the sake of personal growth:

> *"Sometimes I have to learn from a male teacher, but I should try to accept this situation; it helps develop my interpersonal skills and gives me more confidence… I will eventually have to face similar interactions in the workplace."*

This reflects an understanding that interacting with various teachers, regardless of gender, is beneficial for building confidence and adaptability.

In summary, students' views on the gender of teachers varied widely, with many acknowledging the benefits of female teachers in terms of approachability and clarity of communication. However, there were also observations of gender bias in treatment and recognition that teaching effectiveness is more influenced by individual personality and teaching style than gender alone.

6.2.5 Theme 5: Students' Perspectives on Peer Instruction

Students expressed a variety of perspectives on Peer Instruction (PI), emphasising its benefits and challenges. They also provided some valuable recommendations for improving the adaptation of PI in physics courses. Below is a description of these perspectives, supported by direct quotes from students.

Code 1: Advantages and Effectiveness of PI

Many students recognised the significant advantages of using PI as a teaching method, particularly for promoting active learning and engagement.

Student 1 emphasised the benefits of PI in motivating students to prepare ahead and remain actively involved during lectures by saying,

> *"The new method, which is Peer Instruction, is truly excellent and effective because, in the beginning, it forces the student to study the material, or at least read it to know what they will be taking. During the lecture, you must stay active. The Doctor did it excellently by explaining a section and then giving us a question to confirm our understanding."*

Student 1 also highlighted its impact on enthusiasm, stating,

> *"It increases enthusiasm during the lesson and keeps the person from being lazy. If I were just listening to the lecture, I might not even take notes, feel tired, and let the information pass. But when the PI questions are used, I go and try to solve them, see what I understand and what I don't, and discuss with the lecturer to understand better."*

Student 16 believed in the effectiveness of PI, mentioning,

> *"I believe that peer instruction is a very effective method."*

They elaborated on how it helps students overcome the fear of asking questions:

> *"Some students, for example, feel shy about asking questions. Using this method helps them overcome this barrier, allowing them to discuss with peers, which makes them more familiar with and understanding of the topic."*

Many students recognised the value of PI in fostering engagement and making learning interactive, which stood out in contrast to traditional methods.

Student 17, for example, highlighted the motivational and participatory nature of PI, which enhances students' active involvement and makes learning enjoyable. They stated:

> *"The PI method is definitely more effective. Honestly, it is not just about understanding but also talking and discussing answers with your friends. When you interact with them, you feel enthusiastic and engaged as if you are part of it."*

Similarly, Student 19 appreciated how PI activates students' focus by keeping students mentally engaged during lectures:

> *"Of course, PI, because what is the issue? When the professor just lectures, most of us are dozing off, you know? PI activates the mind."*

PI was acknowledged for keeping students engaged and focused during lectures, contrasting with traditional teaching methods that may lead to reduced attention.

Student 13 expressed a preference for the PI method due to its effectiveness in maintaining engagement:

> *"Oh, of course, the PI method is better, because we all stay focused and do not want to fall asleep. When the lecturer just explains, the concentration is lower."*

This highlights how PI encourages active participation, preventing students from losing focus.

Student 13 also shared that discussions enhance the learning experience:

> *"I feel it is better when discussions happen."*

This suggests that interactive elements in PI contribute to deeper understanding and retention of material.

Student 21 highlighted the interactive nature of PI, which encourages cooperative learning:

> *"It creates interaction. If you don't understand, you can collaborate."*

Student 9 supported the method's effectiveness when appropriately applied, particularly in courses with a practical focus:

> *"It is an effective method because before I apply what I have learned, the questions provided serve as a review of important information from the semester."*

They emphasised that discussing with peers helps retain information:

> *"The method is effective in ensuring that you do not forget information quickly."*

A significant number of students valued the discussion aspect of PI for reinforcing their learning and facilitating a deeper understanding of complex topics.

Student 18 emphasised the importance of discussing with peers because this can help fill in knowledge gaps for better comprehension:

> *"I prefer discussions with my classmates because sometimes I might miss a point."*

Student 2 articulated that discussing questions with peers yields a better grasp of ideas compared to reading slides or books alone:

> *“Discussing the question, especially PI questions with our colleagues and friends, we can get the ideas more easily than when we use slides or read the books.”*

Student 2 expressed that PI is highly effective for making lectures and topics more accessible, particularly in physics:

> *“Yes, I think it is a very important way and it makes the lecture and the topics for students easier than before.”*

Student 19 reflected on how PI helps in solidifying the main concepts, stating:

> *“PI Questions with Dr… was used in Physics 1... This helped understand the main idea of the lesson, making it easier to read the book later.”*

Student 15 noted that discussions helped them with language practice:

> *“Discussions even help us practice asking questions in English, which is beneficial for future use.”*

Code 2: Traditional Teaching vs PI

Students compared PI to traditional teaching methods and expressed clear preferences for it.

Student 11 shared their experience,

> *“I expected to study in the regular way, where the lecturer explains and I take notes.”*

This indicates that traditional teaching methods are often seen as passive. However, Student 11 expressed a preference for PI, adding,

> *“Do you think it would have been just as effective without the PI questions? No, I prefer with the PI questions.”*

This supports the notion that PI questions enhance the effectiveness of the learning process.

Student 14 noted an unexpected level of participation in university compared to school, stating,

> *“I did not expect there would be participation. It turned out there was participation that I had not anticipated because it was not described to me about the university before.”*

This reveals that PI introduces a more dynamic learning environment than the students were accustomed to.

Student 17 expressed initial expectations rooted in traditional methods:
“Honestly, I expected the traditional method and did not expect anything different.”

However, they found PI more effective and engaging compared to merely listening to the lecturer.

> *“The PI method is definitely more effective.”*

Student 20 shared that they initially expected the traditional approach before starting university, and later found that interactive methods brought a dynamic change:

“Honestly, I expected the traditional method... before entering university, I asked my friends who were already in, … and none of them mentioned a different teaching method. described it as traditional with nothing extra.”

Even though PI surpassed their initial expectations, they preferred it because it offered a different, more engaging learning experience. Student 20 added,

> *“I definitely prefer the PI method because it allows students to work in groups and exchange ideas and skills.”*

Student 4 preferred engaging with peers during the lecture as opposed to simply listening to a lecture:

> *“If you understand, you can discuss with your peers, so I prefer the second type where you can discuss with your peers during the lecture.”*

Student 12 also preferred interactive teaching methods similar to PI, stating,

> *“As for the teaching method, I prefer it to be somewhat interactive. The lecturer engages with students, asks questions, and tries to get them to deduce the lesson themselves.”*

Student 20 favoured the PI method of instruction, emphasising its collaborative aspect:

> *“I definitely prefer the PI method because it allows students to work in groups and exchange ideas and skills.”*

Student 16 highlighted the transition from school to university PI experiences:
“Honestly, the university experience was very different from school. Initially, I thought the lecturer would just deliver the lecture, students would take notes, and then leave. I did not imagine there would be interaction, sharing, and exchange of information like that.”

This suggests that adjusting to the interactive nature of PI can be a learning curve for some students. Nevertheless, student 16 added,

> *"I believe that peer instruction is a very effective method."*

Code 3: Perceived Challenges and Limitations

Despite its benefits, students also pointed out challenges associated with PI.

Some students encountered difficulties in adapting to the PI method, particularly in contexts with limited previous exposure.

Student 3 pointed out the limited participation among students:

> *"I did not see much participation, like students explaining to each other or me explaining to another student. The idea wasn't really present according to the definition of PI questions."*

Student 9 shared a perspective that while PI aims to encourage collaborative learning, it can be hindered when peers are not adequately prepared or engaged. They explained,

> *"In terms of discussing with my classmates, I do not prefer it, for a certain reason. Most classmates, about 80% of them, come to class unprepared and do not focus fully on the lecture, and some of them understand slowly."*

Student 9 further elaborated that while student interaction is beneficial, the direct engagement of the lecturer can provide a more structured and reliable learning experience. They stated,

> *"If a student, for example, is above average and starts discussing with their classmates, they feel they don't benefit because the others don't understand much and haven't grasped the material. However, I prefer when the lecturer engages with me so that I'm not just a listener. If I am interactive with the lecturer during the lecture, it is excellent."*

Student 15 favored the multiple-choice questions used in PI for their interactive nature but acknowledged limitations such as it may not fully capture the learning progress of every student. They noted,

> *"The multiple-choice method is good, but it cannot always determine if all students understand clearly."*

Student 13 noted that while discussions can be helpful, they may also lead to occasional lapses in attention.

> *"Sometimes, we might not focus, like I'm speaking from experience, right? ... If the lecturer speaks … and we discuss among ourselves, sometimes I don't focus on specific terms while the lecturer is speaking."*

Student 19 pointed out that the PI experience could vary, especially during online courses, and expressed that Physics 1 was particularly challenging when conducted online:

> *"Physics 1 was online, and it was hell, to be honest. The online tests were difficult, especially with the Moodle system, which limited time and the ability to navigate between questions."*

Student 3 commented on the limited impact of PI, describing it as lacking in effectiveness due to minimal participation:

> *"The strategy, which is Peer Instruction, wasn't that impactful. Also, the questions were mostly conceptual without numbers."*

They felt that PI, as implemented, did not foster enough discussion or peer explanation and that time constraints were an obstacle:

> *"It felt more like a quiz or a question where the student participates, but not enough for explaining. And time constraints made it difficult."*

Student 2 mentioned that during Physics 2 course, which was conducted remotely, there was a lack of PI questions involving peer discussions:

> *"So there's no PI question during the lectures, they... are, but with our lecturer not with our colleagues."*

Student 21 noted the limited practice with problem-solving within lectures:

> *"The problems we solved were very limited during the lecture time, and we did not have experiments or solve many more problems."*

Code 4: Recommendations for Enhancing PI

Students suggested potential improvements for maximizing PI's benefits and overcoming its limitations.

Student 2 believed that incorporating more PI questions would enhance student discussions and understanding:

> *"I think it is better to have more PI questions for students and allow them to discuss."*

Student 19 also highlighted that PI method could be effective by increasing the number of PI Questions,

> *"PI Questions should be used more frequently so that students become accustomed to discussing automatically without feeling shy."*

Student 14 believed in a mix of methods because while student interaction is important, the lecturer's guidance is essential to ensure accuracy. They stated,

> *"The lecture is better because, as I said, the lecturer knows the material well. If a student shares incorrect information, and you follow it, everything based on that could be wrong. With the lecturer, you can be sure that everything is correct… But for long lessons, discussions among students can be better."*

Student 3 emphasised the importance of practical work and problem-solving skills gained from PI:

> *"Practical work is very important; it develops students' practical skills as well as problem-solving skills."*

Student 3 also emphasised that structured problem-solving can enhance analytical skills:

> *"Following steps or protocols in solving problems helps students reach solutions more effectively and enhances their problem analysis skills."*

Student 9 found PI helpful when it involved significant application:

> *"This method was used in one of my specialty courses, and that course had a lot of practical application, so we needed to discuss as a team and talk to colleagues about the questions shown on the screen… It was an effective method"*

Student 21 emphasised that tutorial problems were not reviewed sufficiently, leading to a gap in understanding:

> *"Even the tutorial problems weren't reviewed properly. The instructor would explain, and you'd review them in writing."*

Overall, students had varied yet insightful perspectives on Peer Instruction (PI), recognising both its strengths and limitations. While many recognised its benefits in enhancing participation and reinforcing learning through peer discussion, some felt that its implementation lacked depth, active engagement, or adequate structure. Language was also a factor that influenced their experiences, with some students needing time to adapt to using English for complex concepts. Nevertheless, the use of English in PI was often seen as beneficial for terminology development and understanding. For PI to be more effective,

students suggested improvements in its application, including more structured participation and integration of problem-solving activities.

6.2.6 Theme 6: Students' Perspectives on Pre-Reading

Students expressed varied experiences and attitudes toward pre-reading for physics lectures, highlighting a range of habits, challenges, and strategies that influenced their learning.

Code 1: Benefits of Pre-reading

Several students acknowledged that pre-reading could enhance their comprehension during lectures. Student 1 noted,

> *"Yes, it definitely helps me, because I understand, right? I understand, and I know that if I read and then notice I did not understand a particular point during the lecture, I focus more when that point is explained."*

Similarly, Student 11 mentioned,

> *"Reading before the lecture helped me understand the lecture."*

Student 16 noted the importance of pre-reading, mentioning,

> *"Reviewing before the lecture gives me an idea about the topic the professor will discuss, and this helps me understand more easily."*

This demonstrates how pre-reading can prepare students mentally for lecture content.

Student 17 emphasised that pre-reading made understanding easier when combined with the professor's lecture:

> *"The book in physics is your friend... when you watch the professor's explanation, the information is easier to apply and understand."*

Student 16 highlighted that pre-reading facilitated better engagement during lectures, stating,

> *"Reading the book before the lecture greatly helps the student understand the content... and helps them discuss it with the professor."*

Student 19 acknowledged,

> *"Certainly, reading before the lecture helps me understand the lecture better in English."*

This shows how pre-reading contributes to better comprehension during the lecture.

Student 13 found it beneficial to read the chapter before attending the lecture. Excerpt:

> *“It’s better when we read the chapter before the lecture.”*

Student 16 noted that understanding the symbols and concepts beforehand allowed smoother lecture engagement.

> *“Reading the book before the lecture greatly helps the student understand the content presented by the professor and helps them discuss it with the professor if any issues arise.”*

Student 17 reiterated the idea, suggesting that pre-reading made the professor’s terminology and references easier to follow.

> *“You need to read the book before, and then when you watch the professor’s explanation, the information is easier to apply and understand.”*

Student 21 highlighted the benefit of reading before lectures, noting that while understanding the professor's initial explanations could be challenging, repeated exposure to terms and reading beforehand made the learning process smoother:

> *“After one or two lectures, you start understanding because she repeats the same words... especially if you have read the book beforehand.”*

Student 12 candidly admitted,

> *“I am supposed to read, but honestly, I do not. Haha, it is due to my negligence.”*

This acknowledgement suggests an awareness of the importance of pre-reading but also reflects the challenges in consistently applying it.

Code 2: Preference for Direct Learning During Lectures

A notable number of students preferred focusing on lectures without pre-reading. Student 12 expressed,

> *“Because the professor explains in a very clear way, I feel that if I focus on the lecture alone without reading the book, I can understand from her.”*

This sentiment was echoed by Student 10, who noted,

> *“It does have an impact, but I feel that physics requires me to attend the lecture and understand without needing to read beforehand.”*

This student also noted that attending lectures was more effective for them than pre-reading:

> *“I feel that attending the lecture and understanding from it is better than reading beforehand.”*

Student 13 also admitted they do not read before the lecture, explaining that the professor points out key elements during the session, which helps them focus on essential information. Pre-reading on their own led to an overload of information, making it difficult to discern what was significant. This process improved with the professor's guidance.

> *"Because the professor highlights important points during the lecture, and we focus on them. If I read the book before, I might read too much information and not know how to organise it."*

Student 5 relied heavily on the lecturer's explanations, expressing that they did not see significant benefits from reading the textbook.

> *"I honestly did not read… I depended more on the lecturer than on the book."*

Student 6 preferred to let the professor explain first and then refer to the book for clarification. They believed that pre-reading could lead to misunderstandings without the professor's guidance.

> *"I was never convinced that a student should read the book before the lecture itself... I preferred that the professor explains first, then I go back to the book."*

Code 3: Challenges with Pre-reading

Some students mentioned difficulty in maintaining a pre-reading habit due to time constraints or personal preference. For example, Student 1 said,

> *"To be honest, sometimes when I have time, I read. But sometimes, when I have a busy schedule with many lectures and a packed timetable, I do not get the chance to review the lesson."*

Similarly, Student 11 admitted,

> *"I did not always read because there wasn't enough time."*

These quotes illustrate that while students recognised the potential benefits of pre-reading, practical limitations often prevented them from doing so consistently.

Student 14 emphasised that time constraints often made pre-reading difficult.

> *"We don't have enough time, honestly, I feel there is not enough time, so I don't read."*

Student 20 highlighted that preparing from the book would have been beneficial, but they often avoided it due to time constraints.

> *"I initially had the idea that I needed to prepare before the lecture to at least understand when the professor explained. However, due to reasons such as time constraints, I couldn't find the opportunity to finish all the work in one day."*

Student 15 believed that being prepared before a lecture is ideal but not always feasible. They acknowledged that sometimes, due to other responsibilities, reading wasn't prioritized.

> *"I prefer that the student be prepared, but not always in this way. sometimes I read if I find time."*

Student 8 noted that the heavy workload and numerous subjects often prevented them from preparing for lectures as they did in school.

> *"Maybe it's because we have a lot of subjects during the semester, so we don't prioritize preparing for lectures as we did in school."*

Student 19 pointed out that while pre-reading is beneficial, maintaining the habit was difficult due to busy schedules and workload. He said,

> *"By the middle of the semester, it becomes difficult due to the workload, so I don't read at all."*

Code 4: Language and Comprehension Issues

Many students also faced difficulty with understanding concepts and terminology during pre-reading and felt this was a common issue among peers. Student 15 noted,

> *"I honestly faced difficulty. I think most students at my level faced the same."*

And student 10 mentioned,

> *"No, I don't read it because I don't understand."*

Some students struggled with language barriers in pre-reading. Student 11 mentioned,

> *"Some of the terms were difficult and at the same time related to English foundation level?"*

Student 7 found the university textbook dense and difficult, especially transitioning from studying in Arabic to English.

> *"Honestly, the university textbook is very complex and heavy."*

Student 16 sometimes faced difficulty due to language, saying,

> *"There isn't difficulty in terms of the book's content, but sometimes I faced difficulty due to the language."*

Similarly, Student 19 shared,

> *"Physics in Physics 1 was challenging... The difficulty was in understanding the concepts; it was really hard."*

Student 5 attempted to read before the lecture but found it difficult and time-consuming, leading them to abandon the practice.

> *"Before the lecture, I honestly tried to read it, but I found it difficult to read and understand. I tried to translate it… I didn't continue with it... saw it as a waste of time, so I honestly didn't read."*

Student 4 also faced challenges with the textbook.

> *"Yes, there's a lot of difficulty with the book itself. I mean, there is a lot of information; you need to translate it and then understand."*

Code 5: Efforts to Adapt

Students displayed efforts to adapt to pre-reading habits despite challenges.

Student 7 adapted by practicing consistent reading and employing various strategies to become familiar with English terminology.

> *"I kept reading and practicing until I reached a stage where I read beyond the book on physics topics."*

Student 9 favored a strategy where they watched videos first to gain a general overview and then read the book for detailed comprehension. This approach enabled them to grasp the content without needing to review the material multiple times.

> *"I prefer to watch a video first and then read the book... encourages me to read and understand the book quickly."*

Student 19 often combined different sources for better understanding:

> *"I write the lesson title on YouTube, watch it, and then return to the book to read, ensuring I understand the basic idea."*

This strategy shows that using multimedia resources alongside textbooks can enhance comprehension.

To overcome language barriers, Student 16 mentioned using translation tools:

> *"I used translation because physics, in general, is mostly laws and problems... I could overlook some unclear terms."*

Student 17 added,

> *"Google Translate solves everything,"*

highlighting the use of technology to aid understanding.

Student 11 highlighted using translation tools for better understanding:

> *"If I don't understand, I use Google, haha."*

Student 4 noted that understanding the context in Arabic was their primary approach, rather than relying on translation.

“I go back to older school textbooks in Arabic and read them... compare them to the English lessons... helps me understand the terms.”

Code 6: Using Alternative Resources

Students who faced challenges with reading the book often resorted to other resources. Student 12 shared that instead of consistently relying on the book, they would turn to YouTube for additional explanations:

“If I need an explanation different from the professor’s, I go to YouTube.”

Student 7 also mentioned that although videos were more straightforward for learning, reading provided greater depth.

“Videos are easier than reading... but reading provides more benefit than videos.”

When the book was difficult to understand, Student 14 turned to YouTube as an alternative.

“When I don’t understand the book, I watch YouTube.”

Student 8 preferred videos over reading, as they found it easier to digest and more practical. They acknowledged that pre-reading helped with faster comprehension but admitted not having tried it extensively.

“Yes, for some topics I feel it’s better than reading; I prefer to watch a video.”

Student 2 expressed a mixed approach to pre-reading. Sometimes, they would read the textbook but often preferred watching YouTube videos because they found the text difficult to understand. Videos provided them with a clear, brief overview of the lecture topic, aiding comprehension during class.

“Sometimes I read it, and sometimes I prefer watching videos from YouTube because sometimes I don't understand the meaning of the text in the book. So, I go to YouTube to watch a short video before the lecture to understand the main idea of the lecture.”

They also mentioned using translation tools for complicated terms before turning to YouTube for a better understanding if needed.

“Sometimes, I encounter problems with new definitions and words, so I don’t understand them. Sometimes I use the Translate app to get the meaning in Arabic and then start to understand, but when I still have difficulties, I go to YouTube to watch a video before the lecture for background understanding.”

Student 3 preferred interactive learning over reading. While they acknowledged some level of preparation through videos, they were not particularly motivated by the textbook, especially as the professor criticized it, which discouraged its use:

> *"The textbook... was even criticised by the professor. This criticism didn't encourage us to use it."*

Student 3 believed that video explanations were more engaging than static reading and provided a better understanding:

> *"I think seeing a live person explaining is better than just reading from a book."*

Student 20 admitted that despite knowing the importance of preparing for lectures, language issues often prevented them from doing so. They relied on slides instead, though they noted that slides lacked detailed content and were just summaries. For better understanding, they would watch YouTube videos after lectures, especially in Arabic, as this approach was easier for grasping complex lessons:

> *"Studying physics in English at university was challenging at first... watching YouTube tutorials in Arabic after my lectures helped me understand the lesson."*

Student 4 mentioned that they did not engage in pre-reading due to the complexity of the textbook. They found the material difficult and sought alternative sources, such as YouTube or websites, to better comprehend the content.

> *"The book's method feels difficult, a bit complicated... we search for other sources, like YouTube or other websites."*

Student 4 mentioned that using videos and stopping them to take notes was helpful.

> *"He writes on the board, and I write with him. I pause the video."*

This reliance on YouTube indicates that while the textbook was sometimes helpful, students often found other media, such as YouTube, more accessible or informative.

Student 15 preferred using lecture slides over the textbook, finding them more straightforward and directly linked to what was taught in class.

> *“The slides don’t differ from the book; they were in English, and sometimes I would study from the slides.”*

Student 18 preferred slides over the textbook, stating,

> *“We had slides as an alternative, and the professor was great at focusing on the key points. Important things were highlighted, and everything was prepared for us.”*

This indicates that students might find prepared lecture materials more accessible than full textbook readings.

Code 6: Experience with Reading Quizzes

Some students appreciated modifications to pre-reading practices within their courses. For example, Student 1 mentioned an improvement between Physics 1 and Physics 2:

> *“In Physics 1, the reading quiz before the lecture carried marks, but in Physics 2, it did not, and I think that is better... I did notice you improved this in Physics 2 by removing the grades for reading quizzes, and I think that is great.”*

This indicates that pre-reading assessments can impact student attitudes and their approach to preparation.

Student 13 mentioned that in Physics 1, there were reading quizzes that made students read before class. In Physics 2, the absence of such quizzes allowed for more flexible preparation.

> *“In Physics 1, we had reading quizzes, but in Physics 2, we did not. This helped us because we were required to read the lesson before class.”*

Overall, the students’ feedback about pre-reading reflected mixed experiences and views. While some students recognised the value of pre-reading in being prepared to engage effectively with lectures, others struggled due to time constraints, workload, textbook language complexity, and the need for guidance on important content. Some students preferred direct learning from lectures over reading the textbook. Other students used alternative resources like translated terms, videos, and lecture slides to supplement students' learning and help bridge gaps when pre-reading posed difficulties.

6.2.7 Theme 7: Students' Perspectives on Context-Rich Problems (CRPs)

Students expressed a range of opinions about Context Rich Problems (CRPs), with some finding them helpful for understanding concepts, others found the experience frustrating due to time constraints, unclear instructions, and difficulty in connecting them with the curriculum. Below are some of their key insights.

Code 1: Benefits of CRPs

Some students found CRPs beneficial, especially for linking physics concepts to real-world applications. Student 17 found CRPs valuable for understanding tests, stating:

> *"It was good. It helped us honestly, context-rich problems were very good and useful, especially for understanding the tests."*

Student 9 also mentioned that CRPs provided an excellent opportunity for understanding the material better, particularly in the tutorials:

> *"In the university, there is great application, especially in the tutorials, which helps me understand the material better."*

Several students expressed that CRPs helped them apply theoretical knowledge to real-world scenarios. Student 16 appreciated the real-life context of the problems, saying:

> *"The content of the problem was from a real-life perspective. It presented a problem to us, and the level of the problem was high."*

This allowed students to apply their knowledge in practical situations, but it also led to discussions, as it was difficult for one student to solve the problems alone. Student 16 further mentioned:

> *"In my opinion, it requires discussion among group members because if it's presented to one student, they might not be able to solve it completely, so they need to discuss it with peers or even with the professor."*

Some students struggled to see the immediate relevance of the problems at first. Student 18 initially thought the CRPs were random and not related to the curriculum:

> *"At first, I felt it wasn't related to the curriculum, it was random questions..."*

However, he later realised that the CRPs provided

> *"important questions with beautiful ideas,"*

which helped strengthen their understanding. He later appreciated the value of CRPs, saying:

> *“I think CRP is a great idea, and I hope it continues.”*

Code 2: Challenges of CRPs

Despite recognising the benefits of CRPs, many students expressed significant challenges associated with this approach. Some students found the CRPs difficult to understand and struggled with their application. Student 18 found the language of the CRPs challenging:

> *“Unfortunately, no, because it was just a story for the CRP, the problem with it was that these questions go deeper. They do not give you basic words, they provide a story format.”*

This included terms they did not understand, and extra information was provided that was not needed:

> *“Moreover, it gives you extra information beyond what you need, so you need to figure out which parts to focus on.”*

Student 15 echoed this sentiment, feeling that the CRP method was flawed because students could not even check if they were solving the problem correctly:

> *“Okay, we may arrive at the calculation, but it felt like applying the sheet exactly, but I could not even check if the student was solving the sheet properly. I feel like the method is flawed, and I told the teacher to change this, because we are not benefiting.”*

Some students were frustrated with the CRP approach, particularly regarding the clarity and the method of instruction. Student 15 expressed frustration with the CRP methodology, where they needed to fill in a specific answer sheet that follows a particular problem-solving strategy, saying,

> *“No, even the answer sheet for these problems... I told the teacher this is one of the worst things I see in university, the most important thing is for the student to understand the concepts, how they solve things.”*

They also noted that the repetitive nature of the questions made the process tedious:

> *“And I feel like the repetition, when we get one question, and see the entire question repeated, it feels like it has based on these concepts*

from the start. It takes time and also does not allow solving the problems."

Student 15 also reflected on how CRPs were structured:

"I thought the student should literally solve a question once in a while, but instead, we get a question with a whole hour dedicated to solving it like a story. The sheet is not clear, and the student does not understand it until the end of the semester. After the session, the teacher explained, and after 14 weeks, I finally understood what to do."

Several students mentioned the time constraints when solving Context Rich Problems (CRPs). Student 11 felt that the time was limited, stating,

"Yes, but the time was limited, it was a set time."

They felt that time constraints hindered the process and limited their ability to engage with the CRPs thoroughly.

Student 11 also acknowledged that while CRPs helped connect physics to reality, they were time-consuming:

"Yes, because... I do not know, but it helps us connect physics to reality, but it takes a long time until we fully understand."

Several students emphasised that collaboration was crucial for solving CRPs.

Student 16 highlighted the importance of group work, stating,

"In my opinion, it requires discussion among group members because if it is presented to one student, they might not be able to solve it completely."

Student 8 also spoke about the value of grouping students based on their abilities, saying,

"So, in the tutorials, they distribute students based on these abilities, like those who understand faster, to interact with students who don't discuss or who may not understand the topic."

Some students suggested improvements for how CRPs could be better integrated into the learning process. Student 9 proposed that the professor should assign students to groups based on their abilities, saying,

> *"The professor should divide the students into groups based on their level, ensuring a balance. For example, in each group, there should be one low-level student, one average-level student, and one high-level student to make sure the groups are balanced."*

In summary, while students recognised the educational value of Context Rich Problems, especially in applying knowledge to real-world situations, many felt frustrated by the time constraints, unclear instructions, and the lack of immediate feedback. Suggestions for improvement included more collaboration, clearer instructions, better structuring of the problems, and stronger connections between lessons and lab work.

6.2.8 Theme 8: Students' Perspectives on Traditional Problem Solving

Students provided a range of perspectives regarding traditional problem-solving practices in their physics education experiences. The data collected from various students were categorised into several key codes. Below is a detailed summary of the views from various students.

Code 1: Tutorial Effectiveness

Student 12 reflected on their initial enthusiasm for tutorials, stating,

> *"At first, I would attend the whole tutorial. Then, I realised I did not benefit from it much."*

This was due to factors such as a lack of preparation and a scheduling conflict with another class:

> *"I was also a bit late because I had a calculus class just before the lab class."*

The student noted that they were directed to work in a group,

> *"At first, we tried solving individually, but then they told us, 'No, you must solve it together.' So, we solved everything together."*

However, they felt pressured by the limited time,

> *"...the tutorial time is limited."*

This limitation led to rushed solutions and minimal progress:

> *"During that hour and a half, I only solved one question. I felt I wasted my time."*

Code 2: Challenges of Problem Solving

Student 13 emphasised the contrast between school and university instruction in terms of problem solving:

> *"The teaching in school was much more about the teacher. We would wait for her to solve the problems with us, but university teaching is different."*

They described a more independent approach at university, where

> *"The doctor would only upload the chapter solutions at the end of every two weeks."*

Student 13 found that while instructors provided solutions, they often failed to explain their methods thoroughly:

> *"The doctor would upload his solution for the tutorial but wouldn't explain how he arrived at the solution."*

This often leads to confusion, especially when encountering complex problems or symbols:

> *"Sometimes we didn't even understand the symbols he used."*

Student 13 also pointed out the challenges of seeking further explanations:

> *"Even when we asked the doctor a question... he wouldn't answer it if it was not from the pre-chosen questions."*

The lack of real-time engagement was particularly frustrating when tutorials were held online:

> *"It was online, so we couldn't go to him. It was a bit frustrating."*

Student 14 highlighted the need for more practice in problem-solving in their physics education:

> *"I feel physics needs more practice, like in the tutorial... The more practice we have, the more the information sticks."*

Student 20 also noted the reliance on theoretical learning in physics courses:

> *"We did not solve many problems. We relied more on the theoretical part."*

They advocated for the inclusion of more practical problem-solving examples:

> *"It would be better for teachers to include more examples and problems in the lessons."*

Student 15 expressed difficulty in transitioning from theory to application:

> *“We need to understand how to use the formula. How and when to apply it? I have never seen a teacher explain physics in the way I want.”*

Even minor changes in problems caused confusion:

> *“If the change is small, it confuses me. I cannot solve a problem, even a moderately difficult one.”*

The student emphasised the importance of instructors raising questions during lessons:

> *“The teacher should raise questions about the material, for instance, asking why we did not use a particular law.”*

This practice would help students develop a deeper understanding and critical thinking skills.

On the other hand, student 19 criticised the scheduling of tutorials after quizzes:

> *“We had the tutorial after the quiz, which was not ideal... You may have read the book, but you have not started solving problems, and then you have to take the quiz without having the tutorial.”*

This lack of preparation hindered students' ability to apply their knowledge effectively during assessments.

Student 21 acknowledged that time limitations restricted problem-solving opportunities:

> *“This point might be due to time constraints, as there are only three sessions.”*

They suggested having online sessions for additional problem-solving practice:

> *“If there were online sessions where students could ask questions, that would be great.”*

In summary, students highlighted several challenges associated with traditional problem-solving in their physics courses. These included limited tutorial effectiveness, insufficient explanations from instructors, a lack of practical application, and inadequate scheduling of tutorials. They recommended solutions such as increasing interactive problem-solving, integrating more practical examples, and holding additional online support sessions to enhance learning outcomes.

6.3 Summary and Integration of Interview Results

Teachers and students shared several overlapping perspectives on Peer Instruction (PI) and its related practices, yet their views also revealed distinct differences in emphasis and experiences.

Teachers' and students' interviews highlighted the dynamics of language use in classroom interactions where English is the primary language of instruction, but Arabic is frequently used. Teachers noted the challenges of English language barriers that affect students' participation and comprehension. They also noted that students often use Arabic during group discussions and even switch between languages (code-switching) to enhance understanding. While some teachers supported this flexibility, others also emphasized the importance of reinforcing English proficiency. Teachers also emphasized the importance of simplifying the English language to students and using visual aids to support comprehension.

On the other hand, students expressed their discomfort with English, often feeling anxious about speaking it, which leads them to prefer Arabic for discussions. They acknowledged the effectiveness of using Arabic for clearer communication among peers, while also recognizing the necessity of English for technical terms. Students also indicated that their background context influenced their language choices in discussions and interactions with teachers. Many of them expressed a preference for Arabic-speaking teachers, as this facilitates better understanding and engagement.

Regarding the cultural factors, teachers highlighted cultural norms, particularly regarding gender differences, that influence classroom dynamics. In general, they observed that male students tend to dominate discussions, while female students are often more engaged and assertive. Teachers also noted that students often exhibit formal behavior, which may stem from cultural expectations emphasizing respect and formality in educational settings. This formality resulted in a classroom environment where students were less likely to engage in informal interactions. Conversely, students highlighted the challenges of transitioning from school to university, particularly in larger class sizes, which increases anxiety and reduces opportunities for meaningful interaction with professors. They felt that communication and relationships were closer in school, leading to a sense of detachment in university settings. Moreover, students had various perceptions of teacher gender, suggesting that while gender may influence interactions, individual teacher characteristics and teaching methods are more significant in determining effectiveness.

From the teachers' perspective, the benefits of PI were clearly articulated. They emphasized that PI increased student engagement by fostering an interactive learning environment. Teachers also highlighted that PI enhances understanding through collaboration. Moreover, they observed that PI builds student confidence. On the other hand, teachers acknowledged the challenges students face in adapting to active learning, recognizing that they come from a background of passive learning. In contrast, students' perspectives on PI were characterized by a mix of appreciation and apprehension. Students acknowledged the advantages of PI. Many students felt that PI increases their enthusiasm and engagement. However, students also expressed concerns about the effectiveness of PI due to their peers' lack of preparation and participation. Additionally, while they appreciated the collaborative aspect of PI, some students expressed a preference for direct engagement with the lecturer.

Regarding the perspectives of teachers and students on the practice of reading the textbook before physics lectures. Teachers generally recognised the benefits of pre-reading, such as enhancing students' comprehension, fostering critical thinking, and promoting long-term learning habits. However, they also noted significant student resistance, often attributed to cultural habits of passive learning, workload challenges, and preferences for alternative learning methods like videos. On the other hand, students expressed mixed feelings about pre-reading. While some acknowledged its benefits for understanding lecture content, many struggled with time constraints, language difficulties, and a preference for direct learning during lectures.

Teachers generally viewed Context Rich Problems (CRPs) as beneficial for developing critical thinking and problem-solving skills. They appreciated that these problems reflect real-life scenarios and can be culturally relevant. However, they also acknowledged the challenges posed by language barriers, noting that students may struggle with the English language used in these problems, which can detract from their understanding of the physics concepts. On the other hand, students had a more varied response to CRPs. Some found them beneficial for understanding concepts and applying theoretical knowledge to real-world situations. However, many students also expressed frustration with the format and clarity of CRPs. Furthermore, the language of these problems posed a significant challenge for students and complicated their understanding.

Regarding traditional problem-solving methods in physics education, teachers expressed mixed feelings about the effectiveness and relevance of traditional problem-solving, recognising its benefits in building foundational skills and acknowledging its limitations, especially when students are passive participants. While some teachers discarded it totally from their teaching practices, other teachers advocated for a balanced approach that combines traditional problem-solving and context-rich problems to enhance learning. On the other hand, students stated several challenges they faced with traditional problem-solving, including ineffective tutorials, insufficient instructor explanations, and a lack of practical application. They suggested improvements such as more interactive problem-solving sessions and additional online support to enhance their learning experiences.

Overall, while teachers focused on the systematic benefits of PI and its role in enhancing learning, students emphasized their personal experiences and the challenges they faced in adapting to this method.

Teachers, in general, recognised the importance of maintaining English as the primary language of instruction, but they also valued the role of Arabic in enhancing student comprehension and engagement. Students, on the other hand, prioritised effective communication and often preferred Arabic for discussions, especially in informal settings, while still acknowledging the necessity of English for technical terms. Their experiences highlighted the interplay between language proficiency, comfort, and cultural context in shaping classroom interactions.

These divergences in the views of teachers and students highlight the need for strategies that can bridge the gap between these perspectives.

Chapter 7
Conclusion

In educational settings, the application of Peer Instruction (PI) is influenced by a mix of language and cultural factors that play a crucial role in the success of its implementation. The study focused on exploring how PI affects physics education within a setting where English is the primary language of instruction, while students' native language is Arabic. The research results highlight the significance of addressing the challenges that arise due to language and cultural differences when adopting teaching methods across various educational systems.

The data collected through pre- and post-FCI assessments, CLASS surveys and interviews revealed critical insights into the performance and attitudes of students in physics courses. The overall low pre-FCI scores, averaging 21% to 26%, indicated a compelling need for pedagogical reforms to enhance conceptual understanding in physics. The slightly better performance of students taking the pre-test in Arabic, despite being statistically insignificant, raises some questions about the impact of language on learning outcomes. The differences in the patterns of the dominant misconception in the two languages suggest that language comprehension plays a critical role in how students engage with complex scientific concepts.

Moreover, the analysis of concept understanding based on course major and gender revealed significant gaps that demanded further exploration. Engineering students consistently outperformed their science counterparts, suggesting that the teaching approaches in engineering may be more beneficial to fostering understanding in physics. This finding invites educators to consider how instruction can be designed or modified to bridge the gap in performance between different disciplines. Gender differences in performance, particularly in the English version of the FCI, also highlighted the need for targeted interventions to support female students in physics, an area that has seen lower female participation and achievement in literature.

The qualitative data gathered from think-aloud interviews provided deeper insights into the cognitive processes of students as they navigated physics concepts in Arabic or English. The persistent misconceptions identified in both language versions of the FCI suggested a systemic issue in physics education that goes beyond language barriers. Students' struggles with terminology and concepts often stem from a lack of effective instructional strategies that account for their linguistic background. This finding emphasised the necessity for

educators to adopt a more inclusive approach that recognises and addresses the diverse language proficiencies of their students.

The exploration of PI as a teaching method during the COVID-19 pandemic further complicated the landscape of physics education. The low normalised gains observed in both the traditional and PI groups suggested that the shift to online learning may have hindered the effectiveness of both instructional strategies. The challenges faced by remote learning and the inherent difficulties of language comprehension underscore the need for innovative teaching methods that can engage students in a virtual environment.

Teachers' and students' perspectives on PI revealed rich views of experiences that highlighted the complexities of implementing this instructional strategy in a linguistically and culturally diverse setting. Teachers recognised the potential of PI to foster engagement and collaboration among students, yet they also acknowledged the barriers posed by students' English language proficiency. The code-switching observed in classroom discussions illustrates the adaptive strategies that students employ to navigate their language challenges. However, the discomfort expressed by students regarding their English-speaking abilities points to a broader issue of confidence and anxiety that must be addressed to facilitate effective peer interactions.

The cultural factors influencing classroom dynamics cannot be overlooked. The observed gender differences in participation and engagement reflected cultural norms that shaped student behaviour in educational settings. Teachers' efforts to create an inclusive environment must consider these cultural dynamics to encourage equal participation among male and female students. Additionally, the transition from high school to university presented challenges for students, particularly in larger class sizes where meaningful interactions with instructors become more difficult. This transition requires a revision of how PI can be effectively implemented to foster a sense of community and support among students.

The mixed responses to pre-reading and context-rich problems further illustrated the need for a nuanced approach to physics education. While teachers recognised the benefits of these practices, students often resisted them due to cultural habits of passive learning and the complexities of language. This disconnect indicates that educational reforms must not only introduce effective pedagogical strategies but also consider the cultural and linguistic contexts in which students are taught.

Based on these findings and insights, there are several suggestions for enhancing the implementation of PI and advancing the teaching of physics across

language and cultural contexts. First, they offer training programs for teachers that emphasise the importance of sensitive teaching methods. This training should provide educators with tools to address students' language requirements effectively, encourage productive peer conversations, and establish an educational atmosphere that respects diverse perspectives.

Second, educational institutions should consider incorporating language assistance services to assist students in improving their language proficiency in the language they use throughout the academic curriculum like physics concepts and terminology workshops and tutoring sessions can be provided to help students enhance their grasp of the language used in educational settings promoting active participation, in group discussions and cooperative learning activities.

Third, it is important to create teaching materials that are culturally inclusive and easy to understand linguistically as well. Craft problems with context while paying attention to the language used so that students can grasp the situations without facing language obstacles. Moreover, offering resources in two languages might help students with limited language skills better comprehend and engage in the learning process.

Finally, creating a culture of cooperation and communication between teachers and students is fundamental for the successful implementation of PI. Effective channels for feedback need to be set up to enable students to share their opinions and experiences on teaching approaches. At the same time, teachers should clearly explain the reason behind their chosen pedagogical approaches. When students understand the purpose and benefits of these methods, they are more likely to engage in their learning meaningfully. This two-way dialogue enables teachers to refine their strategies based on informed and collaborative feedback.

In conclusion, the discussion on implementing Peer Instruction in a culturally diverse setting brings about various barriers and possibilities to significantly improve the teaching of physics field education. The results of this research emphasise the importance of considering the language and cultural factors that impact students' academic achievements. By embracing a strategy that values inclusivity, provides language assistance, and fosters teamwork among students and teachers alike, we can establish a more efficient and interactive learning atmosphere that encourages grasping concepts and promotes favourable attitudes towards physics. Implementing instruction involves more than just transferring a teaching method from one place to another. It is about grasping the complex dynamics involved and adjusting to accommodate the unique requirements of every student in a specific context.

7.1 Recommendations for Future Research

1. Cross-Cultural Comparative Studies: These Studies should aim to compare the implementation of PI in various cultural settings worldwide and analyse how cultural perspectives on education and collaboration impact the effectiveness of PI in different countries. Through these comparative studies, it would be beneficial to explore the adjustments needed for PI implementation in different educational settings.

2. Longitudinal Studies on Attitudes and Learning Gains: Researchers can study how PI impacts students' attitudes towards physics and their academic performance across semesters to gather insightful information on the lasting advantages of PI methods. Additionally, they could observe how students' language skills develop and how this relates to their engagement and achievements in physics courses.

3. Student-Centered Investigations: Future research should explore issues from the students' point of view, using methods like focus groups to understand how they interact with the PI. Exploring students' responses to various teaching approaches and their language preferences during discussions can help significantly improve teaching techniques.

4. Incorporating Technology in PI: Online and hybrid learning settings are becoming more prevalent in education today. It is suggested that upcoming research focus on how technology can improve PI methods, particularly in bilingual classrooms. Potential areas of investigation may involve the utilization of discussion forums and interactive tools to encourage collaborative learning among peers while also addressing language challenges.

Appendix A

An example of a context-rich problem and the answer sheet

You have been asked to fasten your seatbelt before taking off from Muscat International Airport in a long flight of approximately 19 hours to visit Kennedy Space Center in Florida via Oman Airline. The Airplane (Boeing 777-300ER, mass = 350 ton when loaded) reaches the beginning of the runaway and waits permission from the Airport Tower to take off. After the pilot receives the go ahead signal, he accelerates the two engines to produce a thrust of 500·kN per engine. The airplane needs to reach a takeoff speed not less than 350 km/h before reaching 70% of the length of the runaway that has a total length of 4.0 km. The pilot has to make calculation in order to ensure safe take off, assuming the mass of the airplane remains nearly the same.

PHYS2101
Answer Sheet

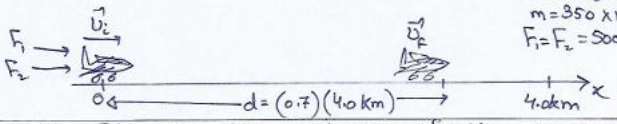
Week:	Tutorial: 6	Group:	Grade: /20

Manager:	ID:	Questioner:	ID:
Recorder:	ID:	Energizer:	ID:

UNDERSTAND THE PROBLEM

Picture and Given Information /2

$v_i = 0$, $v_f = ?$
$v_{f,min} = 350\,km/h$
$d = 2.8\,km$
$m = 350 \times 10^3\,kg$
$F_1 = F_2 = 500.\,kN$



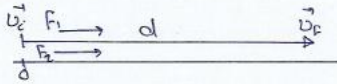
Question(s) - Calculate the velocity of the airplane at 70% of the length of the runway and compare it the the needed velocity of 350km/h /1

Approach - Calculate work done by engines on airplane. /2
- Calculate initial and final kinetic energy of airplane and apply work-kinetic energy theorem.

EXPLAIN THE PHYSICS

Diagram and Known Quantities with Needed Conversions /2

$v_i = 0$
$v_f = ?$
$d = 2.8\,km$
$m = 350 \times 10^3\,kg$
$F_1 = F_2 = 500.\,kN$
$v_{f,min} = ?$



Target Quantity(ies) $v_f = ?$ /1

General Equations /2

$$W = \Delta K$$
$$Fd\cos\phi = \frac{1}{2}m v_f^2 - \frac{1}{2}m v_i^2$$

PLAN THE SOLUTION

Use General Equations to Derive Specific Equations /3

$F_1 d \cos\phi + F_2 d \cos\phi = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$

$2Fd = \frac{1}{2} m v_f^2$

$v_f = \sqrt{\frac{4Fd}{m}}$

Check Units of Final Equations /2

$v_f = \sqrt{\frac{kg\,m\,s^{-2}\,m}{kg}} = m/s$ ✓

APPLY THE PLAN

Calculate Target Quantity(ies) /2

$v_f = \sqrt{\frac{4(500. \times 10^3)(2.8 \times 10^3)}{350 \times 10^3}} = 126.5\,m/s \sim 130\,m/s$

$v_f = \frac{126.5\,m}{s} \times \frac{1\,km}{10^3\,m} \cdot \frac{3600\,s}{1\,hr} = 455\,km/h$

$\sim 460\,km/h > v_{f,min}$

EVALUATE THE ANSWER

Is Answer Properly Stated? Explain. /1

Yes. The SI unit for velocity is m/s.

Is Answer Reasonable? Explain. /1

Yes. The answer is within the range of the given velocity of take off.

Is Answer Complete? Explain. /1

Yes. The final velocity was found to be 460km/h which is greater than $v_{f,min}$ → take off is safe.

Appendix B

Colorado Learning Attitudes about Science Survey (CLASS)

Name: _____ **Last 6 digits of your Student ID #:** _____

Introduction

Here are a number of statements that may or may not describe your beliefs about learning physics. You are asked to rate each statement by circling a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

Survey

1. A significant problem in learning physics is being able to memorize all the information I need to know.

Strongly Disagree	1	2	3	4	5	Strongly Agree

2. When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.

Strongly Disagree	1	2	3	4	5	Strongly Agree

3. I think about the physics I experience in everyday life.

Strongly Disagree	1	2	3	4	5	Strongly Agree

4. It is useful for me to do lots and lots of problems when learning physics.

Strongly Disagree	1	2	3	4	5	Strongly Agree

5. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

Strongly Disagree	1	2	3	4	5	Strongly Agree

6. Knowledge in physics consists of many disconnected topics.

Strongly Disagree	1 2 3 4 5	Strongly Agree

7. As physicists learn more, most physics ideas we use today are likely to be proven wrong.

Strongly Disagree	1 2 3 4 5	Strongly Agree

8. When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.

Strongly Disagree	1 2 3 4 5	Strongly Agree

9. I find that reading the text in detail is a good way for me to learn physics.

Strongly Disagree	1 2 3 4 5	Strongly Agree

10. There is usually only one correct approach to solving a physics problem.

Strongly Disagree	1 2 3 4 5	Strongly Agree

11. I am not satisfied until I understand why something works the way it does.

Strongly Disagree	1 2 3 4 5	Strongly Agree

12. I cannot learn physics if the teacher does not explain things well in class.

Strongly Disagree	1 2 3 4 5	Strongly Agree

13. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.

Strongly Disagree	1 2 3 4 5	Strongly Agree

14. I study physics to learn knowledge that will be useful in my life outside of school.

Strongly Disagree	1 2 3 4 5	Strongly Agree

15. If I get stuck on a physics problem my first try, I usually try to figure out a different way that works.

Strongly Disagree	1 2 3 4 5	Strongly Agree

16. Nearly everyone is capable of understanding physics if they work at it.

Strongly Disagree	1 2 3 4 5	Strongly Agree

17. Understanding physics basically means being able to recall something you've read or been shown.

Strongly Disagree	1 2 3 4 5	Strongly Agree

18. There could be two different correct values to a physics problem if I use two different approaches.

Strongly Disagree	1 2 3 4 5	Strongly Agree

19. To understand physics I discuss it with friends and other students.

Strongly Disagree	1 2 3 4 5	Strongly Agree

20. I do not spend more than five minutes stuck on a physics problem before giving up or seeking help from someone else.

Strongly Disagree	1	2	3	4	5	Strongly Agree

21. If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.

Strongly Disagree	1	2	3	4	5	Strongly Agree

22. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

Strongly Disagree	1	2	3	4	5	Strongly Agree

23. In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.

Strongly Disagree	1	2	3	4	5	Strongly Agree

24. In physics, it is important for me to make sense out of formulas before I can use them correctly.

Strongly Disagree	1	2	3	4	5	Strongly Agree

25. I enjoy solving physics problems.

Strongly Disagree	1	2	3	4	5	Strongly Agree

26. In physics, mathematical formulas express meaningful relationships among measurable quantities.

Strongly Disagree	1	2	3	4	5	Strongly Agree

27. It is important for the government to approve new scientific ideas before they can be widely accepted.

Strongly Disagree	1	2	3	4	5	Strongly Agree

28. Learning physics changes my ideas about how the world works.

Strongly Disagree	1	2	3	4	5	Strongly Agree

29. To learn physics, I only need to memorize solutions to sample problems.

Strongly Disagree	1	2	3	4	5	Strongly Agree

30. Reasoning skills used to understand physics can be helpful to me in my everyday life.

Strongly Disagree	1	2	3	4	5	Strongly Agree

31. We use this statement to discard the survey of people who are not reading the questions. Please select agree-option 4 (not strongly agree) for this question to preserve your answers.

Strongly Disagree	1	2	3	4	5	Strongly Agree

32. Spending a lot of time understanding where formulas come from is a waste of time.

Strongly Disagree	1	2	3	4	5	Strongly Agree

33. I find carefully analyzing only a few problems in detail is a good way for me to learn physics.

Strongly Disagree	1	2	3	4	5	Strongly Agree

34. I can usually figure out a way to solve physics problems.

Strongly Disagree	1	2	3	4	5	Strongly Agree

35. The subject of physics has little relation to what I experience in the real world.

Strongly Disagree	1	2	3	4	5	Strongly Agree

36. There are times I solve a physics problem more than one way to help my understanding.

Strongly Disagree	1	2	3	4	5	Strongly Agree

37. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.

Strongly Disagree	1	2	3	4	5	Strongly Agree

38. It is possible to explain physics ideas without mathematical formulas.

Strongly Disagree	1	2	3	4	5	Strongly Agree

39. When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.

Strongly Disagree	1	2	3	4	5	Strongly Agree

40. If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

Strongly Disagree	1	2	3	4	5	Strongly Agree

41. It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct.

Strongly Disagree	1	2	3	4	5	Strongly Agree

42. When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.

Strongly Disagree	1	2	3	4	5	Strongly Agree

Appendix C

Peer Instruction in Physics: Evaluating effects of language and culture.	UNIVERSITY OF LEEDS

PhD RESEARCH PROJECT School of Physics & Astronomy

Principal Investigator: Ms. Rahma Al Harthi
PhD Project Supervisors: Dr. Alison Voice and Dr. Samantha Pugh

INFORMATION SHEET

Overview of research project

Over recent years at Sultan Qaboos University (SQU), there has been a noticeable decline in the students' performance in introductory physics courses accompanied by a drop in the number of students who choose physics as their major of study. To counter this, Peer Instruction is being introduced in several physics classes and this research project will evaluate its effectiveness, looking particularly at aspects of language and culture. When the students' first language is not the language of instruction there may be unique challenges to effective peer discussion in physics. And when the culture from high school has been to take instruction from the teacher, discussion in class may be hard to establish. Through observation of classes, interviews with staff and students, along with pre- and post-tests of understanding and attitudes, this project will provide a rich understanding and evaluation of this medium of instruction in physics with wide applicability. The effect of students' major/minor subjects will also be investigated. Recently, remote teaching provided some extra challenges, which we want to investigate.

How will the research be conducted?

This research will evaluate the students' performance and attitude in four introductory courses namely physics I for science and Physics 1 for engineering. This is done by use of surveys at the beginning (pre-test) and at the end (post-test) of each course. Students will fill mechanics survey (45 minutes) and attitude survey (10 minutes). This research will also involve students' interviews on voluntary basis and class observations.

Who can participate?

We invite all students registering in physics I courses to take part in the research, but participation is voluntary, and no reason needs to be given if you choose not to take part. You can also participate, but decline to answer specific questions at any time if you wish.

Will it be anonymous?

For Surveys: All responses to surveys will be anonymous and you will not be identified after the research analysis or output. We will use your ID number only for analysis purposes and then it will be removed.

For Interviews: Interviews will be also anonymous and no student can be identified.

What will happen to the data?

Mechanics survey will be conducted on paper (in case of face-to-face instructions) or online (in case of online teaching). Attitude survey will be conducted online only. Class observations will be conducted online or face- to-face depending on the situation. All results will be transferred to electronic files for analysis. The anonymised data will then be stored securely in an open access/ institutional repository for at least 10 years. Data collected will be used only for the purpose of this research project. Findings from the research will be published so others can benefit from the new understanding.

Are there any benefits or drawbacks to taking part?

We don't expect there will be any drawbacks to taking part, or deciding to not take part, in the research. Your participation will be extremely beneficial to the Department of Physics, in helping us to understand how students learn through peer instructions, how factors like culture or language affecting their learning process, and how we can better support students learning in the future.

What should I do if anything upsets or concerns me after taking part?

We don't expect the research surveys or interviews to cause you concern, but if they do, you can contact the principal researcher.

Can I withdraw once I have participated?

You are able to withdraw your response to any of the surveys within 14 days of completing it. In such a situation, no reason is required, but only data from that survey can be withdrawn from the study, as any data collected earlier may already have been analysed. If you wish to withdraw at any stage or have any questions or issues, please contact the principal investigator. You can also withdraw your response to a class observation or an interview within 14 days of conducting it.

What will be done with the findings?

1) The principal investigator will be publishing a PhD thesis that will discuss aspects of the research, in a fully anonymised way.
2) We will present our findings at education conferences involving national or international destinations and audiences, and publish in education peer reviewed journals.

Research team contact details

If you have questions about this study, you can contact: Rahma Al Harthi, e-mail: rahmah@squ.edu.om

This research has been approved by the University of Leeds' Maths, Physical Sciences and Engineering Ethics reference: MEEC 20-004

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