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Inquiry-Based Learning Model for Teaching the Concept of Force in Malaysian Matriculation Colleges

Shariza Shahari
Universiti Teknologi Malaysia, Malaysia
Email: shariza79@graduate.utm.my

Fatin Aliah Phang
Universiti Teknologi Malaysia, Malaysia
Email: p-fatin@utm.my

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Abstract
The study evaluates the use of Inquiry-Based Learning (IBL) in teaching force concepts at Malaysian matriculation colleges, utilizing the 5E Learning Model. IBL emphasizes active, student-centered learning, fostering critical thinking and problem-solving skills. However, implementing IBL faces challenges such as insufficient training, limited resources, and the need for structured guidance. This research aims to identify the inquiry levels used by lecturers and their impact on students' understanding of force. Using a mixed-methods approach, data was collected through classroom observations and semi-structured interviews. The findings indicate significant improvements in students' conceptual understanding of force when IBL is employed, particularly with lower-level inquiries like Confirmation Inquiry (CI) and Structured Inquiry (SI). These methods help students build foundational skills before progressing to higher-level inquiries. Thematic analysis found that the main roles of IBL during the learning of force concepts are conceptual understanding, correlation between concepts, application in real-world contexts, concept reinforcement, and understanding signs or symbols. Despite challenges, lecturers who used IBL observed increased student engagement and improved learning outcomes. The research underscores the importance of varied inquiry levels in science education, demonstrating that low-level inquiries effectively prepare students for more complex investigations. The study also emphasizes the need for additional training and resources to support effective IBL implementation, suggesting that a tailored IBL model can significantly enhance physics education at the pre-university level in Malaysia.
Keywords: Inquiry Based Learning, Force Concept, 5E Learning Model, Mixed Method, Physics

Introduction

Inquiry-Based Learning (IBL) is a pedagogical approach that emphasizes active, student-centered learning where students engage in questioning, investigating, and constructing their understanding of scientific concepts (Fernandez, 2017; Sim & Mohammad Yusof Arshad, 2014). This approach aligns with constructivist learning theory, which posits that learners build new knowledge based on their prior experiences and interactions with their environment (Vygotsky, 1978). IBL encourages students to take ownership of their learning, fostering critical thinking and problem-solving skills (DiBiase & McDonald, 2015; Kaya et al., 2016), and a deeper understanding of complex topics like force in physics.

Despite the benefits of IBL, lecturers at Malaysian matriculation colleges face challenges in implementing various IBL models in their physics classrooms. These challenges include insufficient training and resources, time constraints within the curriculum, and the need for more structured guidance on effectively integrating IBL into their teaching practices (DiBiase & McDonald, 2015; Kaya et al., 2016). Additionally, some lecturers find it challenging to shift from traditional, teacher-centered methods to a more student-centered approach, which requires significant changes in classroom management and instructional strategies. This is particularly relevant when teaching intricate concepts like force, which demand a deep conceptual understanding and application.

This study aims to evaluate how matriculation lecturers teach the concept of force using IBL and how the IBL models they use can enhance learning in this specific area of physics. By examining current practices and experiences of lecturers, this research seeks to identify the strengths and weaknesses of existing IBL implementations and provide insights into how these models can be improved and adapted to better meet the needs of students and educators. This research is particularly relevant in improving teaching methodologies and student outcomes in physics education at the pre-university level in Malaysia.

Literature Review

The 5E Learning Model (5ELM) is a model that is often used in the implementation of IBL (Bybee & Landes, 1990). 5ELM, which consists of five phases namely Engagement, Exploration, Explanation, Elaboration, and Evaluation, emphasizes student-focused activities, as shown in Table 1. This table outlines the phases of the 5ELM and provides a description of the activities and roles of teachers and students at each phase. Through these phases, students are actively involved in the learning process by exploring, explaining, developing, and evaluating their knowledge continuously.

Table 1
Description of the 5E Learning Model (Bybee & Landes, 1990)

Phase	Description
Engagement	- The teacher stimulates the students' minds to evoke curiosity.
	- The teacher introduces the context.
	- The teacher elicits the students' prior knowledge.
Exploration	- Students build conceptual understanding based on hands-on activities.
	- Students conduct guided or open investigations to answer the questions that have arisen.
	- Students seek information/data using various sources.
	- Students conduct investigations to generate new ideas or solve problems.
	- Students design and implement investigations.
Explanation	- Students construct explanations and extended ideas through reflection on the investigations conducted.
	- The teacher provides input to review the conceptual understanding built by the students.
Elaboration	- Students expand their conceptual understanding through application in new situations.
Evaluation	- Evaluation occurs at each phase to assess students' progress.
	- Encourages students to evaluate their understanding and abilities.

A study by Tural et al. (2010), found that the implementation of 5ELM was effective in helping students understand scientific concepts such as 'no weight'. The phases in 5ELM, particularly exploration, explanation, and expansion, allow students and teachers to share ideas and understand concepts through effective interaction, in line with social constructivism theory. Gillies and Rafter (2020), also found that the use of 5ELM in IBL can promote scientific literacy among primary school students. Through inquiry-based activities, students are given the opportunity to explore and solve problems together, thereby increasing their understanding of the scientific phenomena under investigation. This study shows that 5ELM can stimulate students' curiosity and understanding in science learning.

5ELM offers a structured and systematic approach that allows teachers to give clear instructions and provide a framework for learning. By stimulating students' interest early in the process and assessing their understanding at the end, 5ELM guides teachers in providing a comprehensive teaching and learning (TnL) framework for deep and directed learning, making it a suitable choice in this study.

However, despite the strengths of the original 5E Learning Model, there is a need to adapt and enhance it to better suit the educational context in Malaysia. In many Malaysian science classrooms, the approach to inquiry-based learning tends to lean more towards structured methods where teachers play a significant role in guiding the learning process. To address this, the model can be refined by integrating specific roles of inquiry at each phase, allowing for a more targeted and manageable implementation of inquiry-based learning. This enhancement will provide teachers with a clearer framework that aligns with their instructional practices while still promoting active student engagement. Adapting the model to the local context ensures that it is more practical and effective in fostering a deeper understanding of scientific concepts in Malaysian classrooms.

Objectives

The main objectives of this study are:

1. To identify the inquiry levels used by lecturers who implement IBL through the 5E Learning Model (5ELM) in their physics classes, specifically when teaching the topic of force.
2. To measure the impact of different inquiry levels on students' level of understanding of force before and after the implementation of IBL through the 5E Learning Model (5ELM).
3. To develop an IBL-based teaching model for the concept of force to enhance students' understanding and improve teaching strategies for lecturers.

Methods and Instruments

This study employs a mixed-methods approach, combining qualitative and quantitative data collection. The sample includes three physics lecturers (P1, P2 and P3) who use Inquiry-Based Learning (IBL) in teaching the topic of force, along with their students. Classroom observations provided insights into how lecturers implement IBL for force, focusing on strategies to engage students and the challenges faced. Semi-structured interviews with lecturers offered qualitative data on their experiences and perspectives on IBL implementation. Thematic analysis by Braun and Clarke (2006) was used to identify patterns and themes, providing a deeper understanding of lecturers' experiences and practices in implementing IBL for teaching force.

IBL is classified into four levels: confirmatory inquiry, structured inquiry, guided inquiry, and open inquiry (Heather & Randi, 2008). Confirmatory inquiry involves confirming known principles, structured inquiry has students follow set procedures, guided inquiry allows students to design their own procedures, and open inquiry involves generating their own questions and conducting full investigations.

Lower levels of inquiry such as confirmatory and structured inquiry help students consolidate ideas and practice basic skills before moving on to more complex open-ended inquiry. Guided inquiry, where students design their own procedures with teacher guidance, provides more opportunities for students to learn to design experiments and record data. Finally, open-ended inquiry allows students to fully act as scientists, generating questions, conducting investigations, and communicating their results. The study shows that guided inquiry is often practiced by teachers, especially in TnL science, and all levels of this inquiry are important in changing students' misconceptions of scientific concepts such as force (Heather & Randi, 2008). Table 2 outlines the different levels and types of IBL, with the type of information provided to students at each level.

Table 2
Indicators for the Level and Types of Inquiry Based Learning (IBL) (Heather & Randi, 2008)

Level of Inquiry	Type of Inquiry and Characteristics	Questions	Procedures	Solutions
1. Confirmation Inquiry (CI)	Students confirm a principle/concept through an activity where the outcome is already known.	√	√	√
2. Structured Inquiry (SI)	Students investigate a question provided by the teacher using given procedures.	√	√	-
3. Guided Inquiry (GI)	Students investigate a question provided by the teacher using procedures designed by the students.	√	-	-
4. Open Inquiry (OI)	Students investigate a question generated by themselves using procedures designed by the students.	- Teacher does not provide questions, procedures, or solutions. - Students are given full opportunity to generate questions, design and conduct investigations, and present their results.		

Results

The study's findings indicate a significant improvement in students' conceptual understanding of force after the use of IBL (Shahari & Fatin Aliah, 2023). The significant improvement in students' understanding of force concepts supports previous findings by Fernandez (2017) that highlight the effectiveness of IBL in science education.

Thematic analysis found that the main roles of IBL during the learning of force concepts are i) conceptual understanding, ii) correlation between concepts, iii) application in real-world contexts, iv) concept reinforcement, and iv) understanding signs or symbols. By engaging students in inquiry-based activities, they are better able to grasp fundamental concepts and see the connections between them. This method also allows students to apply their knowledge in practical situations, thereby making learning more relevant and meaningful. In the excerpt below, the teacher (P1) provides understanding to the student(s) (S) by asking them why tensile force is not drawn in the free-body diagram (FBD). The students respond that if there is no rope on the object, then the tensile force does not exist.

P1 : Why you didnt draw the tension? Why we didnt draw the tension?
S : Takde string
P1 : Yes. It didnt attached to a string. So we dont draw the tension aa..tak attached kepada sebarang string"

On another example, in the excerpt below, the teacher asks students to assign a meaningful symbol to the tensile force for a free-body diagram (FBD) that the students have drawn. As a result of this symbol, students can understand that even though different objects are involved, the tensile force is the same when using the same rope.

"P1 : ..So, untuk object ni, tali hujung belah sini kan, so tension dia ke sini..keluar dari objek..ok? So, yang ini pula?
S : Ke atas

P1 : Yes good. Tali yang tu ke atas. Keluar dari objek, sometimes dia jadi T_1 dan T_2 loh, sebab dia adalah tali yang? Sama. So, tension dia sa? Sama..Give it the same symbol..”

Both excerpts explain that the teacher uses specific questioning techniques and symbolic representations to deepen students' understanding of tensional force using FBD. In the first excerpt, the teacher clarifies that tensile force is not depicted if there is no string attached to the object. In the second excerpt, the teacher guides students to use a consistent symbol for tensional force, emphasizing that the force remains the same when the same rope is involved, regardless of the different objects. These teaching strategies help students grasp the conditions for depicting tensional force for objects connected by the same string.

Based on thematic analysis from classroom observation, it was found that all teachers, P1, P2, and P3, used confirmation inquiry (CI), while P1 and P3 also incorporated Structured Inquiry (SI). The use of both types of inquiry by P1 and P3 led to higher score improvements among their students. Both types of inquiry used by P1 and P3 are considered low-level inquiry methods for teaching the concept of force. This finding aligns with Heather and Randi's (2008) study, which indicates that low-level inquiry is common and observable in science classrooms. These low-level inquiries help students gradually develop their skills for engaging in higher-level inquiries in the future.

The implementation of these inquiry methods highlights the importance of using varied inquiry levels in science education. While low-level inquiries are more frequently used, they effectively build a foundation for students to enhance their inquiry abilities over time. This approach ensures that students progressively improve their understanding and application of scientific concepts.

To further encapsulate the role of IBL, we developed a comprehensive 5E Learning Model (Bybee & Landes, 1990) incorporating the five key roles of IBL as in Figure 1. This model outlines how each phase (Engage, Explore, Explain, Elaborate, and Evaluate) contributes to five roles of IBL during the learning of force concepts. This structured approach, which includes the use of low-level inquiry methods such as Confirmation Inquiry (CI) and Structured Inquiry (SI), provides a clear framework for lecturers to enhance their teaching strategies and improve students' comprehension of force.

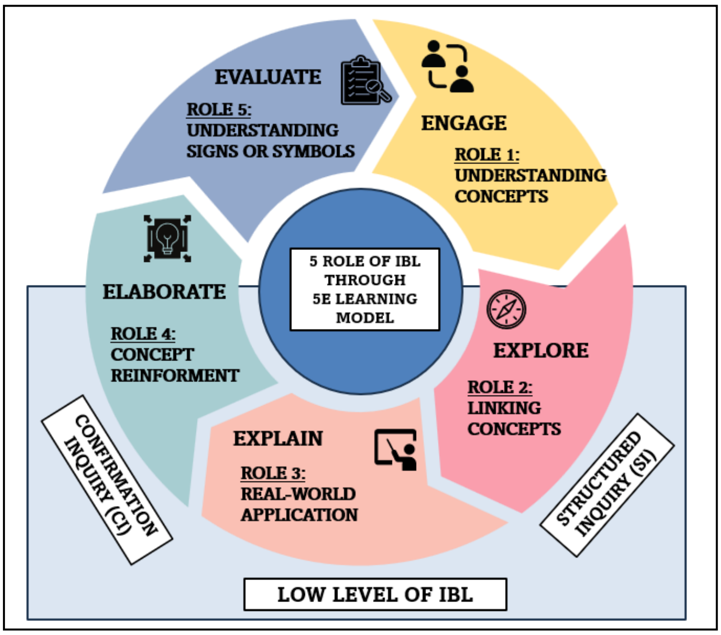

Figure 1 : 5E Learning Model with Roles of Inquiry-Based Learning (IBL) for Teaching the Concept of Force

Discussion

Model from this study enhances and complements the original 5E Learning Model by Bybee & Landes (1990) by integrating specific inquiry roles at each phase. While the original 5E model focuses on general phases such as Engagement, Exploration, Explanation, Elaboration, and Evaluation, this enhanced model incorporates five distinct inquiry roles that include understanding concepts, linking concepts, real-world application, concept reinforcement and understanding signs or symbols.

This addition not only guides students through the phases of learning but also ensures a deeper level of engagement and comprehension through structured inquiry, particularly at the lower levels of IBL like Confirmation Inquiry (CI) and Structured Inquiry (SI). As such, the new model provides a more holistic and contextual approach to fostering scientific understanding.

This new model is more suitable and beneficial for teachers in Malaysia because it aligns with the prevalent teaching practices and curriculum standards, especially in science education. In the Malaysian context, most classrooms employ lower levels of inquiry, specifically Confirmation Inquiry (CI) and Structured Inquiry (SI), where students follow guided instructions or verify concepts rather than engaging in open-ended investigations. By embedding these specific inquiry roles within each phase of the 5E model, this enhanced framework provides clear, structured guidance that Malaysian teachers are already familiar with. It allows them to foster inquiry-based learning without the need for extensive resources or time, making it more practical and feasible for the typical Malaysian classroom setting. Additionally, it offers a smoother transition for students to gradually develop higher-order thinking skills, building on a foundation they are already accustomed to.

Conclusion

This study demonstrates the significant impact of IBL on students' understanding of force in Malaysian matriculation colleges. The findings indicate substantial improvement in students' grasp of force, with pre-test and post-test results showing better performance when IBL is implemented (Shahari & Fatin Aliah, 2023).

IBL plays five crucial role during the learning of force concept; understanding and linking concepts, applying knowledge to real-world scenarios, reinforcing concepts, and interpreting scientific signs or symbols. By engaging students in inquiry-based activities, they better understand fundamental concepts and their interconnections. This method allows students to apply their knowledge in practical situations, making learning more relevant. The study's results align with previous research, showing that inquiry-based strategies can significantly enhance student learning outcomes (Kaya et al., 2016). Furthermore, IBL helps students develop essential skills in interpreting scientific symbols and signs, crucial in physics education.

Classroom observations highlighted the challenges lecturers face in implementing IBL, mainly due to time constraints and limited resources. Despite these challenges, lecturers increased student interaction and engagement through hands-on experiments, problem-solving sessions, and collaborative group work. These activities were particularly effective in enhancing students' understanding of force.

Qualitative data from interviews underscore the need for additional training and structured support for lecturers to implement IBL more effectively, especially for complex topics like force. Lecturers noted that while IBL enhances engagement and understanding, more structured guidance and resources are necessary to overcome practical difficulties. Integrating real-world examples and interdisciplinary approaches could further enrich learning and make the concept of force more relatable.

In conclusion, the study underscores the potential of a tailored IBL model to improve teaching and learning of force in physics at the matriculation level. With appropriate support and modifications, IBL can enhance student outcomes in physics education (Gillies, 2020).

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