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Implementing the 5E inquiry model in an online platform of a flipped classroom environment

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In light of COVID-19 outbreak and the subsequent closures of educational institutions, the need for online environments has significantly increased. This study sheds light on the online component of a mathematics flipped classroom (FC) and aims to investigate if, and to what extent, it can effectively utilize inquiry-based learning (IBL). Based on the 5E inquiry model, the study focuses on an advanced mathematics course for high-school students taught in an FC environment. Analysis of seven filmed lectures on the subject of complex numbers was conducted using a validated 5E inquiry model scoring instrument. Results indicate promising findings for a wisely planned virtual platform that answers the 5E model requirements and may successfully demonstrate an IBL-supported environment.

Keywords: Inquiry-based learning, flipped classroom, 5E Model, mathematics education

Introduction

The difficult period resulting from the COVID-19 outbreak, which includes, among other things, the closure of educational institutions, has highlighted an urgent need for a worthy alternative to the traditional teaching method (Dhawan, 2020). Most recently, and due to COVID-19 pandemic, a huge variety of online learning environments have emerged. A potential alternative approach is the Flipped Classroom (FC), with the goal to provide students with a supportive environment alongside a deep and meaningful learning experience (Sharkia & Kohen, 2021). The research environment that served this study is a MOOC called Campus IL, an Israeli national digital learning venture, which offers the users the opportunity to experience an advanced and individualized learning process, by providing a huge variety of online content. Particularly, the FC method can be an ideal venue for transforming traditional learning into an engaging, inquiry-based learning (IBL) environment (Love et al., 2015). The FC approach includes two phases, of which the first phase occurs out of class, where students are expected to undergo an independent learning process, while the second phase takes place inside the classroom and involves extensive practice exercises of the materials learned outside of class (Bergmann & Sams, 2012). Previous studies in the field have explored the application of IBL in the physical classes, as the FC approach frees up class time for IBL-type activities (Sharkia & Kohen, 2021). Yet, limited research had been done on the application of IBL in the online component of the FC environment (Love et al., 2015). Thus, the current study aims to investigate the application of IBL in the online platform of an FC learning environment. We aim to explore whether, how, and to what extent an online platform for a mathematics FC utilizes IBL in the most effective way.

Theoretical Background

The FC Approach

Two components comprise the FC approach; the first is the independent learning process that takes place outside of the classroom, and the second is the active and collaborative lessons inside the
classroom (Bergmann & Sams, 2012). The FC approach utilizes various technological means to provide students with instructional materials and related exercises. These technological resources allow students to learn the content outside of class (Dori, Kohen, & Rizowy, 2020), hence offer teachers considerable time in class to provide deeper explanations and practice alongside the students (Bergmann & Sams, 2012). The online component of the FC is where teachers provide filmed lectures, presentations, online assignments, and more, and expect students to independently learn the provided content before arriving to the class. With that, and according to Lo and Hew (2017), this approach promotes student-centered learning experience. Additionally, it allows a wiser management and exploitation of class time, by enabling teachers to roam around the classroom, identifying various individual difficulties, detecting different challenges and misconceptions among the students, and finally react accordingly by giving these students the support and encouragement they need (Lo & Hew, 2017). A main advantage of the class component of the FC approach is that it provides students with adequate amount of class time to extensively and collaboratively work on exercises alongside their teacher, which is considered an essential condition to master mathematical skills and achieve comprehensive understanding of the material (Kaiser & Vollstedt, 2007). A main advantage for the online component of the FC approach is that the instructional content is available for students out of class any time and place, hence they can access it countless times until they accomplish full comprehension (Lo & Hew, 2017). As a result of the COVID-19 pandemic, the “traditional” flipped classroom, in which students meet with the teacher in person, was almost impossible to adopt. Instead many institutions have integrated online teaching with FC. Research has shown that this combination resulted in positive effects on students, including increased learning, comprehension and attention, as well as positive evaluations of a variety of taught courses (Tang et al., 2020).

The 5E Inquiry Model

According to the 5E model (Bybee et al., 2006; Bybee, 2009), learning through inquiry follows five phases, which are identified as follows: (i) engagement, (ii) exploration, (iii) explanation, (iv) elaboration, and (v) evaluation. These phases can be implemented to various levels when planning and constructing different curriculum materials, lesson plans, and instructional strategies (Bybee et al., 2006). Classroom inquiry is composed of five essential characteristics (National Research Council, 2000), which can be addressed by applying the 5E model during the learning process (Schallert et al., 2020). The first characteristic is engaging the learner in scientific questions (National Research Council, 2000, p. 29). This feature can be found in the first phase of the 5E model, namely, engagement, which enables students to engage in the learning activities. In this phase, teachers need to motivate and engage students by presenting a certain problem that requires students’ attention. The next phase is exploration. As soon as students are engaged and motivated in a certain activity, they should be able to explore their thoughts and abilities. In this phase, classroom inquiry is characterized by prioritising the evidence in response to questions, and formulating explanations based on evidence (National Research Council, 2000, p. 29). The next phase of the 5E model is explanation, in which concepts, ideas, procedures, and skills become clear and understandable. This phase relates to another inquiry characteristic that comprises explanations connected to scientific knowledge and communication and justification of explanations (National Research Council, 2000, p. 29). The explanation phase describes these features, offering students the opportunity to create connections
between their explanations to scientific knowledge and further justify them. The next phase is the elaboration of the problem and its solution(s). In this phase teachers provide students with further experiences, tasks and challenges aiming to expose them to new but similar situations. The final phase of the 5E model is the evaluation, in which teachers are expected to provide their students with the appropriate feedback on the quality of their performance. Figure 1 presents visually the 5E inquiry model.

![5E Inquiry Model](image)

**Figure 1: The 5E inquiry model (Schallert et al. 2020, based on Bybee and colleagues’ model, 2006)**

The research question of this study is: How, and to what extent, the online platform of the FC can effectively utilize the IBL approach.

**Method**

**Research Environment - Campus IL**

The current study focuses on one course that is held in Campus IL. Campus IL is a joint venture from Digital Israel and the Council for Higher Education that aims to provide all Israeli citizens the opportunity to pursue education and engage in intellectual development. This environment includes a huge variety of courses and resources from highly respected colleges, universities and other academic organizations. Having gained access to Campus IL, the user can benefit from a personalized and unique learning experience. The current study utilizes an advanced mathematics course in Campus IL. This course is designed for high school students who study advanced mathematics, and aims not only to prepare them for the final matriculation exam in mathematics that takes place at the end of 11th and 12th grades, but also to expand their horizons and nurture their mathematical thinking and prepare them for first year college mathematics.

All the content of this course is conveyed through short, filmed lectures that were filmed and produced in a specially designed studio at the Technion institution, under the supervision and direction of a professional photography and editing team. The average length of each video is roughly 5 minutes, and it is mostly followed by short assessment tests and quizzes that aim to assess students' comprehension of the mathematical content they have recently watched. Dr. Aviv Censor, one of the outstanding lecturers in the Technion institution (according to national and institutional instructional surveys) is the teacher who delivers the content in all the filmed lectures. In addition, an academic team under his supervision has developed, created, and written all the evaluation tests in a manner that suits the level taught in the videos. Figure 2 presents a screenshot taken of a filmed lecture about the subject of complex numbers.
Research Tools and Analysis

Research tools include a scoring instrument that was developed and validated in a research study conducted by Goldston and colleagues (2013). This scoring rubric was designed to evaluate IBL lesson plans according to the 5E model by Bybee et al. (2006) and is considered a reliable tool for its total reliability score that reached 0.98. It consists of several items for each one of the 5E model phases. Each item is given a score that ranges from 0 to 4, based on a 5-point Likert scale, where 0 stands for unacceptable, 1 is poor, 2 refers to average, 3 means good, and 4 represents excellent. This rubric was also found to help teachers and educators to revise their strategies of how to design a 5E-based lesson. The current study mainly used several sections of this rubric to assist in evaluating filmed lectures, in an attempt to investigate if and to what extent these lectures employ the IBL method. The elements of all phases were considered except for the explanation phase, which is basically based on assessing student perspective, therefore could not be taken into account in the scoring process which evaluates the teacher perspective in the filmed lectures. In the present study, we chose to present the analysis for the first seven filmed lectures which provides introduction to the subject of complex numbers. This subject is part of the advanced mathematics curriculum, that is required in the second matriculation test conducted at the end of 12th grade. These lectures started with three introductory videos, the next two videos explained the emergence of the groups of numbers and provided a definition of a complex number, and the last two videos illustrated the algebraic and geometric representations of a complex number. The videos were transcribed and evaluated quantitively according to the scoring rubric described above. We also present qualitative analysis of the videos, for examining the narratives of IBL that were captured in the videos.

Findings

In order to reveal the exemplification of IBL in the online platform of the mathematics FC Campus IL, a thorough and comprehensive analysis of several filmed lectures was completed. A score was given to each one of the different elements that are characterizing the various phases of the 5E model. Figure 3 below illustrates the means and standard deviations of the scores obtained to the seven filmed lectures. Scores were calculated separately for each one of the four considered phases.
Figure 3: Average scores of the elements composing each phase of the 5E model

Figure 3 shows that all the examined elements were evident in the lectures and reached a score that is higher than 3, meaning that these lectures highly fulfill the requirements for implementing IBL during a mathematics lesson. Besides means and standard deviations, frequency distribution of scores that were given for each component was calculated. See Table 1 reflects the frequency distribution of scores that were given for each component, for all the seven explored filmed lectures.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Score (2)</th>
<th>Score (3)</th>
<th>Score (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement</td>
<td>22.22%</td>
<td>44.44%</td>
<td>33.33%</td>
</tr>
<tr>
<td>Explanation</td>
<td>16.67%</td>
<td>33.33%</td>
<td>50.00%</td>
</tr>
<tr>
<td>Elaboration</td>
<td>11.11%</td>
<td>66.67%</td>
<td>22.22%</td>
</tr>
<tr>
<td>Evaluation</td>
<td>0.00%</td>
<td>0.00%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

It can be seen that score (4) has the highest frequency in both explanation and evaluation components while they have different means. Similarly, score (3) has the highest frequency in both engagement and elaboration components. These differences in the distribution can explain the differences in standard deviation in each component. Specifically, when comparing all four phases, it can be seen that the explanation and evaluation components were the most prominent in the examined lectures. This indicates that the explanation phase that is adopted in the videos largely promotes and contributes to inquiry in the classroom. Particularly, aiming to encourage and promote profound understanding, throughout this phase it was evident that the teacher was determined to introduce concepts that students were unfamiliar with or not aware of. Presenting a great variety of examples and strategies in the filmed lectures, the teacher was able explain these concepts and theories. Another interesting finding that is revealed is that classroom inquiry can be more efficient when the teacher performs evaluation and assessment activities at the end of the lecture.

From a qualitative perspective, we now describe some utterances that were observed in the filmed lectures, which illustrate the appearance of the inquiry components in part of the videos that were analyzed. In the introduction lecture (#1), the teacher opens the lecture with an interesting starting point in an attempt to gain students’ engagement. He asked the students the following: “Did you know
that bears can count to 4?!”. then continues: “When walking in bear-inhabited areas, the instructions recommend staying in groups of at least 5 people, as bears tend to avoid groups of more than four”. Following the intriguing introduction about counting natural numbers, the teacher refers to negative numbers, and asks: “what is -3?” and immediately tries to bring real life examples to illustrate the meaning of negative numbers. He then asks students an interesting question that stimulates students’ knowledge from their early years of study: “Back in 6th grade, you were taught that multiplying two negative numbers results in a positive number. Why is this true? I would like you to pause the video for a moment and try answering this question yourself”. The teacher tries to raise simple yet challenging questions to motivate the students and attain their attention and engagement, this is crucial to assure students will be intrigued to continue watching the next lectures seeking for logical answers. Following, in the second introduction lecture (#2), the teacher enters the explanation phase, in which he intends to answer the previously raised question, and thoroughly explain it to the students. After the explanation phase the teacher moves to the next phase of elaboration revealed in lecture (#3) of the introductory films, in which he presents new problems, yet related to the previous parts of the introduction. This lecture aimed to elaborate the concept of square root of a negative number. He uses simple explanations, examples, and graphs to illustrate that no square root exists for a negative number. And from this point, he mentions the main subject of complex numbers by saying: “There were some who believed differently and raised the idea of imaginary numbers”. He concludes this video by adding that: “Let us consider complex numbers, without which there would be no Einstein relativity, no quantum theory, no autonomous cars, and no noise-cancelling headphones”. Doing so, he emphasizes the importance of mathematics in general and the significance of the complex numbers subject to students’ real life. All the above examples of this teacher’s lectures demonstrate the actual use of IBL in the online platform of the FC, through a variety of wise questions, certain metaphors, and unique delivery methods of the mathematical content. These examples supplement the quantitative findings which indicate a high degree of IBL applied by this teacher in the various online filmed lectures.

**Discussion**

According to the Principles and Standards for School Mathematics (National Council of Teachers of Mathematics, NCTM, 2000), an IBL approach should be integral to and at the core of good instructional practices. Yet, to promote rigorous and meaningful IBL, teachers should constantly strive to improve the quality of inquiry instructional practice (Marshall et al., 2006). In the present study, we provide insights into implementing IBL in mathematics flipped classrooms. It investigates if, how, and to what extent the online platform of the flipped classroom can effectively utilize the IBL approach. Using a validated scoring rubric (Goldston et al., 2013), analysis and scoring of several filmed lectures were accomplished. The findings indicate that the instructional process in these examined lectures exemplify the characteristics of an IBL method. Specifically, findings reveal that
the explanation phase was prominently observed. This finding aligns with several characteristics for IBL defined by the National Research Council (2000). It was evident in the lectures that the teacher tried to raise questions that require the students’ exploration, and subsequently offered them explanations that are science based. Thereby, teaching them to link their own explanation to scientific knowledge which leads to further comprehensible justifications. Another significant finding is that once evaluation process was observed, it indicated an excellence implementation of IBL. According to Bybee (2006), this is a critical phase, which enables not only teachers but also students to evaluate and assess their comprehension. Through applying short quizzes and a variety of tests, teachers may be able to evaluate the improvement of students’ understanding and abilities (Schallert et al., 2020).

From a theoretical perspective, the study contributes to the limited literature about the interrelationship between IBL and FC, particularly referring to the online component of FC. From a practical perspective, we present promising findings indicating that when designed wisely according to the 5E inquiry model, the virtual component of the flipped classroom can represent an IBL environment which students will benefit from, especially in difficult periods such as the current COVID-19 period.

**References**


