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Boosting Motivation and Performance: Interactive Learning in Engineering Sciences

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ABSTRACT

With the increasing need for dynamic and engaging educational experiences, methodologies are essential to captivate and motivate students effectively. As the digital age progresses, students are more accustomed to interactive and multimedia-rich environments, making it imperative for educational strategies to evolve accordingly. This paper proposes a four-phase classroom methodology called ITIF, immersed in an interactive learning platform, and demonstrates its high effectiveness in capturing the students' attention and improving their motivation. Through an interactive learning platform, this methodology merges elements of proven didactic techniques like flipped classroom, peer instruction, and some aspects of other active teaching methods. This platform allows immediate feedback to the student and the teacher so that the educational strategy can be adapted according to the group's progress. The ITIF methodology was implemented in first-year engineering courses with physics and mathematics content. The quantitative measurements indicated that student motivation remained at high levels, and it was also observed that the more students participate in class through the platform, the higher their academic grades. These findings suggest that the ITIF methodology can be a valuable tool for educators, providing a flexible and effective approach to enhance student engagement and academic performance.

Key words: Educational Innovation, Higher Education, Interactive Learning Platform, Motivation, Academic Achievement, Engineering Education

INTRODUCTION

Implementing technologies in education has transformed teaching methods, showing that it is possible to improve student participation and academic performance. (Bower, et al. 2015); (Okojie and Boulder 2020). In this context, interactive learning platforms stand out for their ability to provide immediate feedback and the capability to adapt educational strategies according to the progress of the group in real-time (Mayer 2009); (Bond, Buntins, et al. 2020). Teachers and students can monitor learning progress and adjust pedagogies and study strategies according to needs, significantly increasing academic engagement and performance. (Hattie and Timperley 2007) In addition, continuous feedback promotes deeper learning, especially in complex areas such as engineering (Nicol and Macfarlane-Dick 2006); (Daniel, et al. 2023).

Although different teaching techniques have been explored, and the impacts of interactive platforms have been studied elements (Hew, et al. 2020); (Gorbett, Chapman and Liberatore 2022), few classroom methodologies successfully integrate all of these (Bond, Marín, et al. 2018); (Harris and Jones 2020). Hence, in this work, a new classroom methodology called ITIF (Initial Integration, Trigger, Intermediate Integration, and Final Integration), which integrates all these elements, is presented. ITIF methodology is designed to boost motivation and improve academic performance, through the integration of successful teaching techniques and the use of an interactive learning platform. This paper details the ITIF methodology and the implementation strategy, as well as the measurement of its impact on the motivation and academic performance of the students.

BACKGROUND

Interactive learning platforms are digital tools that facilitate the delivery of educational content and continuous assessment (Bizami, Tasir and Kew 2022). Some of these platforms allow instructors to monitor student progress in real-time and adjust pedagogical strategies according to the needs of the group (Holstein, et al. 2018). Research has shown that the use of these technologies can significantly improve student engagement and academic performance (Bernard, et al. 2014); (Bond, Buntins, et al. 2020).

According to Nicol and Macfarlane-Dick (2006), immediate feedback helps students identify and correct errors quickly, which facilitates deeper and more autonomous learning. In the field of engineering education, continuous feedback has been linked to improvements in the understanding of complex concepts and the application of theoretical knowledge to practical problems (Nicol and Macfarlane-Dick 2006).

In this direction, motivation is a determining factor in academic performance (Pintrich 2003). According to Deci and Ryan (2000); (2020) theory of self-determination, intrinsic motivation is driven by autonomy, competence, and relationships. Interactive learning platforms can increase intrinsic motivation by giving students control over their learning and by providing feedback that reinforces their sense of competence (Romero-Frías, Arquero and del Barrio-García 2020). Studies have shown that motivated students tend to participate more actively in class and have superior academic performance (Ryan and Deci 2020); (Pintrich 2003).

In addition, classroom participation is a key indicator of academic success (Sogunro 2017); (Kuh 2013). Kuh (2013) defines student participation as the amount of time and effort that students dedicate to educational activities that are positive for their development. Interactive learning platforms facilitate this participation by making classes more dynamic and engaging. Research has shown a strong correlation between active participation through these platforms and academic performance, reflected in better grades and greater knowledge retention (Chen, Lambert and Guidry 2010); (Schneider and Preckel 2017).

For the teaching-learning process to be successful, it must be based on an educational strategy (Aji and Khan 2019). There are a variety of validated educational strategies that can be implemented in the classroom, according to the learning objectives and the target group. Some of the most used educational strategies in STEM areas are Problem-Based, Flipped Classroom, Inquiry-Based Learning, Case-Based Learning, Peer Instruction, Gamification, and Game-Based Learning, among others (Nilson and Goodson 2021).

With the objectives of boosting motivation and improving the academic performance of engineering students, in the study of physics and mathematics content, we have designed a methodology that integrates elements of some successful didactic techniques, as well as the use of an interactive learning platform.

ITIF METHODOLOGY

This section outlines the phases of the proposed class methodology. It explains the components of each phase, including the elements of validated educational strategies utilized and the interactive educational platform employed to implement the methodology. It also specifies the types of activities that were used.

Phases of ITIF Methodology

The methodology consists of 4 phases, Initial Integration, Trigger, Intermediate Integration, and Final Integration (Figure 1). The first phase, Initial Integration, is an activity that aims to review the previous concepts that the student must have in mind to successfully approach the class. The

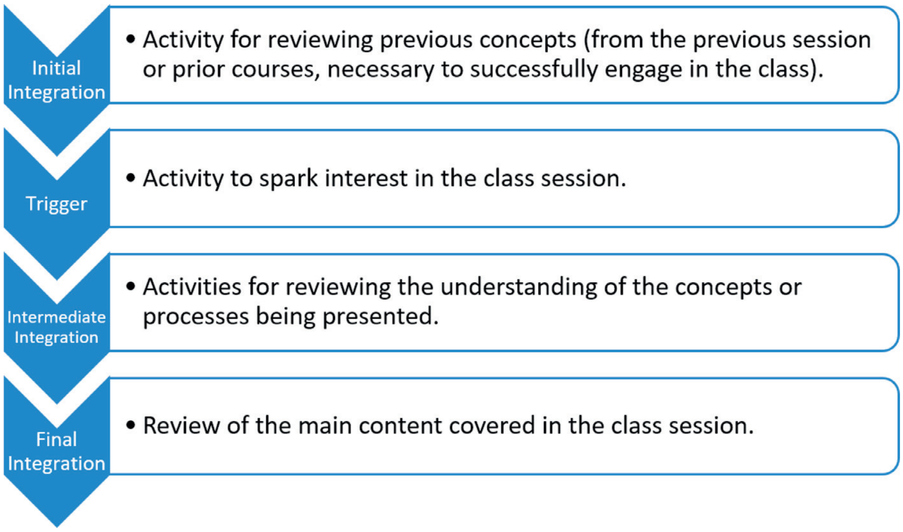

Figure 1. Description of the four phases of ITIF Methodology. Initial Integration, Trigger, Intermediate Integration, and Final Integration.

second phase, called Trigger, is carried out immediately after the initial Integration and consists of an activity that awakens the student's interest in the topic to be addressed. The third phase, Intermediate Integration, is carried out after having presented a series of concepts or methodologies and aims to review the level of understanding of the students. This phase can be carried out more than once in a session and allows the teacher to adapt their explanation according to the result and the student to be sure whether they have understood the content and, if this is the case, to raise doubts. The final phase, Final Integration, is an activity that integrates the main contents covered in the session so that the student can take a clear view of the scope of the class, and the teacher of the progress of the group.

Elements of Educational Strategies

Each phase of the ITIF methodology integrates validated educational strategies, which are described below:

1. **Initial Integration**: This phase aligns with the concept of *prior knowledge activation*, which is crucial for meaningful learning according to Ausubel's theory of learning (Ausubel and Fitzgerald 1961); (Sexton 2020). Reviewing previous concepts helps students connect new information with existing knowledge, thus facilitating better understanding and retention. Teaching techniques such as the *flipped classroom* use a similar strategy where students prepare before class so that they can participate more actively during the session (Abeysekera and Dawson 2015).

2. **Trigger**: Activities designed to spark interest, and curiosity can increase students' intrinsic motivation and engagement with study material. This technique is supported by theories of motivation such as self-determination (Ryan and Deci 2020). Techniques such as concept maps or trigger questions are commonly used in active teaching methods to capture students' attention at the beginning of a lesson.
3. **Intermediate Integration**: Ongoing review and formative assessment during class help reinforce learning and identify areas where students may be struggling. This practice is supported by information processing theory that stresses the importance of repetition and the application of concepts for long-term retention. The Peer Instruction technique developed by Eric Mazur is an example, where students explain and discuss concepts with each other, thus facilitating a deeper understanding (Crouch and Mazur 2001).
4. **Final Integration**: Reviewing the core content at each session's end helps consolidate learning and ensure that key concepts are understood and retained. This strategy is in line with the effect of seriality in memory psychology, which shows that items presented at the end of the session are generally better remembered. Methodologies such as summative review at the end of classes are present in several pedagogical models, including problem-based learning (Tofade, Elsner and Haines 2013); (Murre and Dros 2015).

Interactive Learning Platform

Nearpod is the interactive learning platform chosen to implement the ITIF methodology. Nearpod is an online platform that allows teachers to create interactive lessons that include quizzes, polls, videos, real-time collaborations, and much more (Astarina and Herlinda 2022). The platform offers real-time analysis and feedback tools, allowing instructors to adapt their pedagogical strategies based on student engagement and performance data. (Fuertes-Alpiste, et al. 2023). Studies have shown that in blended or distance learning environments, the use of Nearpod can improve student engagement and academic outcomes. In Hernandez-Mena, *et. al.* (2024) we show the first approximation of this methodology; in this study, Nearpod was used in face-to-face learning environments on hard science content, and it was measured how the use of the interactive platform can significantly improve student participation and attention in physics and mathematics content, compared to traditional classroom methods.

Figure 2 mentions the main Nearpod activities that were used to implement the phases of the ITIF methodology in the class sessions. This includes Interactive videos, Draw it, Fill in the blanks, Time to Climb, Quiz, Matching pairs, Drag and Drop, Open-ended questions, and Phet Simulations, chosen to maintain students' active participation and enhance their engagement with the subject content.

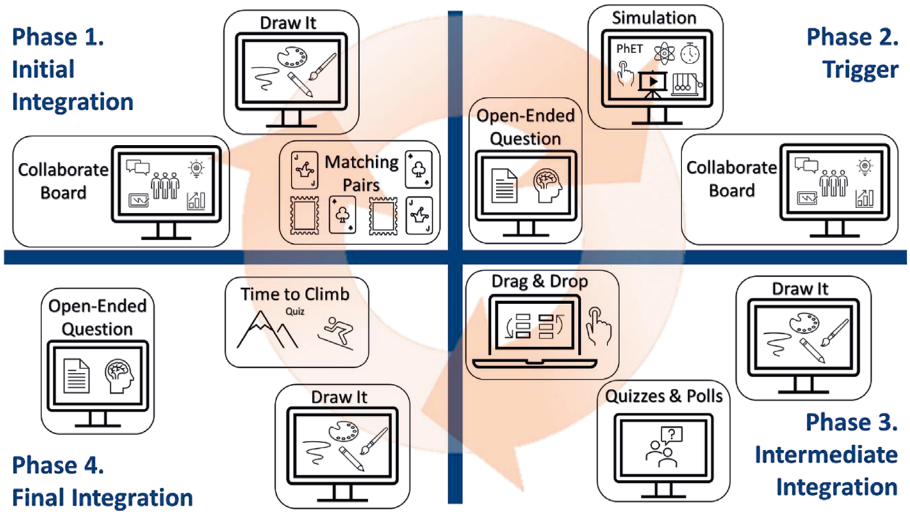

Figure 2. Types of activities used in each phase of the ITIF methodology. Here are presented some of the activities that were used in the sessions.

The following demonstrates the application of the ITIF methodology for the topic Magnetic fields, incorporating the interactive platform Nearpod at each phase.

Phase 1. Initial Integration: This phase focused on activating students' prior knowledge and building a solid conceptual foundation.

- Students used Nearpod's "Draw It" tool to sketch magnetic field lines around a bar magnet (Figure 3). Students work on their outline and the teacher can review each student's schemas in real time. This activity enabled the identification of students' preconceptions about the arrangement and direction of magnetic field lines.

Phase 2: Trigger Phase: The objective of this phase was to spark interest and promote interactive exploration of the phenomenon.

- A PhET interactive simulation of magnetic fields was used (Figure 3), allowing students to manipulate magnets and observe changes in field lines as the magnet's properties were altered. While students explore the simulation, the teacher can show the group different options of the simulation on the screen.

Phase 3: Intermediate Integration: This phase aims to reinforce concepts through practical activities and formative assessment.

- Quizzes and Polls were conducted in Nearpod to assess key concepts, such as the direction and intensity of the magnetic field (Figure 3). This feedback allowed the instructor to tailor explanations to the group's specific needs.

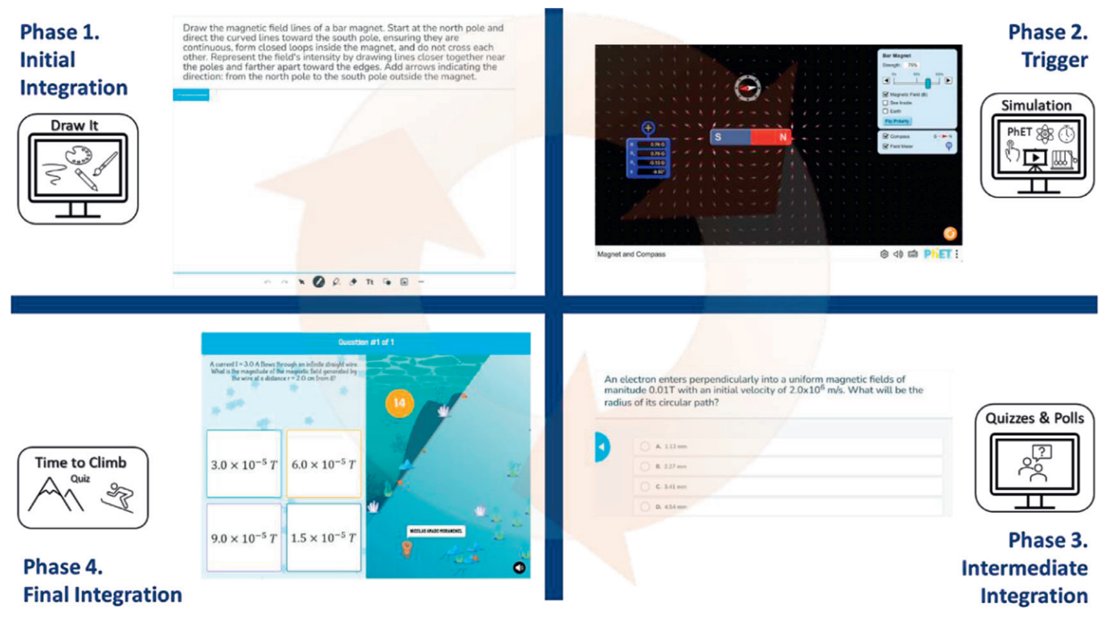

Figure 3. Example of activities used in each phase of the ITIF methodology for a class about Magnetic Field.

Phase 4: Final Integration: The final phase consolidated the learning through synthesis and review activities.

- To conclude, the "Time to Climb" tool provided an engaging and competitive review, encouraging active participation as students revisited the session's key points (Figure 3). In this way, the teacher ends with an overview of the level of understanding of the group.

These characteristics make the ITIF methodology a robust and adaptable proposal that can significantly improve student performance and motivation in engineering sciences, in addition to offering teachers effective tools to monitor progress and adjust pedagogical strategies in real-time, thus optimizing their educational work.

IMPLEMENTATION

The implementation took place during the February-June semester of 2024. The type of course where the ITIF methodology was implemented is called Block, since it includes learning modules from different disciplines: physics and mathematics, through an integrative challenge problem (Olivares Olivares, et al. 2021). The implementation of the ITIF methodology was carried out only during the class sessions of the learning modules of vector calculus (M1), electrostatic (M2), and

Table I. Student distribution in the study.

Group	Number of students	Participation by module	Total participation in the study
1	24	M1	24
2	18	M1, M2, M3	54
3	21	M1, M2, M3	63
4	19	M2	19
5	21	M2	21
6	15	M2	15
Total	**118**		**196**

electromagnetism (M3). Each class session lasts 100 minutes. The activities carried out with the ITIF methodology were not weighted in the students' grades; however, this allowed the teachers to know in real-time the comprehension of the topics.

Population

In total, 118 first-year engineering students participated in this study, of which only 91 fully answered the final survey (incomplete responses were eliminated from the study). Figure 4 shows the ages of the 91 students ranging from 17 to 23 years old. In addition, 63% were men, 36% were women

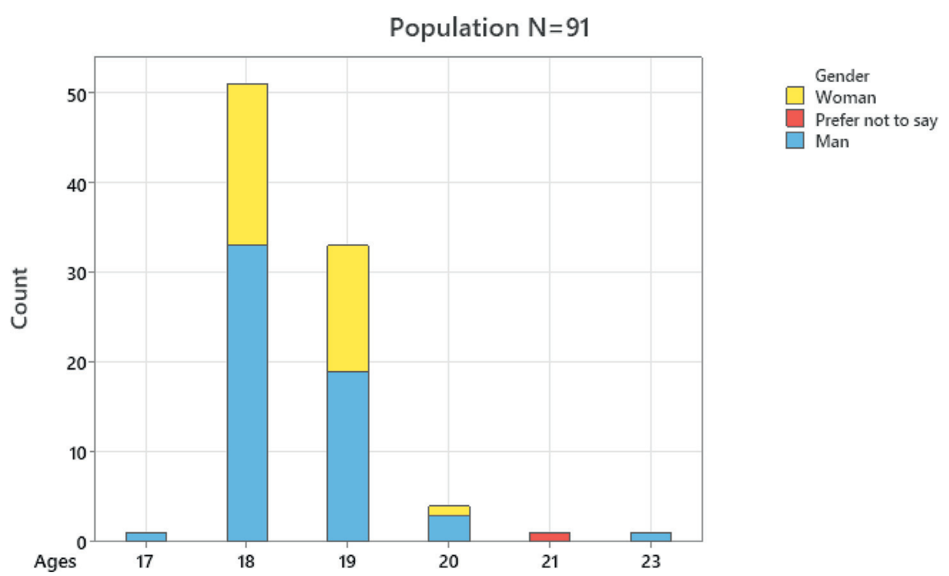

Figure 4. Description of the population. Of 91 first-year engineering students who answered the final survey, 63% were men, 36% were women and 1% preferred not to say their gender. The ages of the students ranged from 17 to 23 years old.

and 1% preferred not to say their gender. It is important to mention that the 118 students signed an informed consent form on the use of data, such as participation and grades.

Class Dynamics

Before the class session, the teacher must configure the interactive activities on the platform, which can be of the type presented in Figure 2 or others the platform offers. At the beginning of the session, the access code is shared with the group, and they are asked to enroll. Once the session is started, the ITIF methodology (Initial Integration, Trigger, Intermediated Integration (as many times as required), and Final Integration) is implemented. At the end of the class, the teacher can access reports from the platform, which include percentages of participation, both individual and group, and specific results by activity for each student and group and analyze them. These subsequent activities enable the teacher to analyze the scope of the teaching strategy and adapt it if necessary. Figure 5 shows this dynamic schematically.

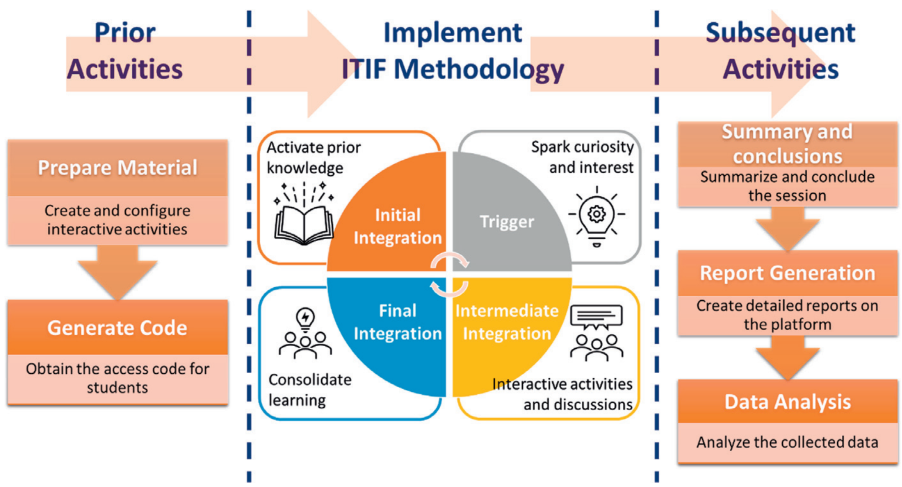

Figure 5. Prior activities, implementation, and subsequent activities conform completed class dynamic.

IMPACT MEASUREMENT INSTRUMENTS

Four types of data were collected to measure the impact of the ITIF methodology:

1. The percentage of participation per student and group for each class was collected by Nearpod reports, which provide detailed student interaction data, including participation percentage and activity-specific details.

Figure 6. Four constructs of motivation: Attention, Relevance, Confidence, and Satisfaction. Motivation in one element from the MAKE evaluation instrument.

2. The academic performance of the students was collected by the grades in modules where the methodology was applied.
3. The motivation of the students was measured through the MAKE evaluation. The MAKE evaluation instrument has four constructs: Motivation, Attitude, Knowledge, and Engagement (Haruna, et al. 2021). This study used just the Motivation construct, which has Cronbach's alpha = 0.92 and comprised four components: Attention, Relevance, Confidence, and Satisfaction (Figure 6). Attention refers to the focus of the student during the learning process; Confidence refers to how independent the student feels about the learned content; Relevance is the recognition that the learning contents were new for the student; and Satisfaction is about the appreciation of the student about how the good organization of topics, learning content, and activities facilitated the understanding of the material and achieved the desired learning (Haruna, et al. 2021). For each component, there are four questions calibrated in the 5-point Likert scale (Haruna, et al. 2019).
4. The perception of the students about the utility of the interactive learning platform (Nearpod) was measured by a four-question survey. Due to the nature of this aspect of the study, this survey is self-authored; the survey was already used in a previous study (Hernandez-Mena, et al. 2024). The items are shown in Table II.

Table II. Survey about students' perception of Nearpod utility.

Items	Abbreviations
The use of Nearpod helped to keep my attention in class	Attention
Using Nearpod distracted me	Distraction
The use of Nearpod improved my learning	Learning
I liked the use of Nearpod	Preference

RESULTS

In this section are presented three findings that demonstrate the positive impact of using the ITIF class methodology. The first result shows the correlation between student participation using the interactive learning platform and their academic performance. The second is the measurement of students' motivation towards the class (MAKE instrument). The third shows the student's perception of the usefulness of the interactive learning platform in the learning process.

Relation between Student Participation through the Interactive Learning Platform and their Academic Performance

As mentioned in the section *Population*, the implementation was carried out in 10 learning modules. Some students participated in multiple modules, so 196 records were counted as it can be seen at Table I. Each student obtained a grade in the learning module, where class activities, assignments, quizzes, and exams were considered. Likewise, each student received an average percentage of participation in class through the interactive learning platform; the rate of participation was calculated considering the Nearpod reports of all the class sessions of the module where the ITIF methodology was implemented. Table III presents the statistical data of the variables Grades and Participation. Figure 7 shows a binned scatterplot of Grades vs. Participation. The diagram exhibits that the highest density of points (71.9% of records) is in the areas of high participation (80% – 100%) and high scores (70 – 100), but also a few (5.1% of records) with some lower scores (40 – 70). This indicates that there is a significant concentration of students who are highly engaged and get high grades. There are some scattered spots in the areas of lower turnout (60% – 80%) and varied ratings, with 16.3% of the students with high scores (70 – 100) and 2.6% of the records with scores lower than 70, but the density is much lower compared to the high-turnout area. In the intervals of participation (0% - 60%) there are just 1.5% of records with grades between 70 – 80 and 2.6% of records with scores lower than 70, there is less concentration of points, suggesting that fewer students are in these categories.

Motivation

At the end of the study, 91 students answered the MAKE survey for the Motivation variable. The result is presented in Figure 8. The boxplot shows an average motivation of 4.2 inside a box which goes from 3.9 to 4.7, and the whiskers go from 3 to 5.

Table III. Statistical data of the variables Grades and Participation.

Variable	N	Mean	StDev	Minimum	Median	Maximum
Grades (1–100 scale)	196	84.416	13.611	18.000	86.900	100.000
Participation (%)	196	87.09	15.01	0.00	91.30	100.00

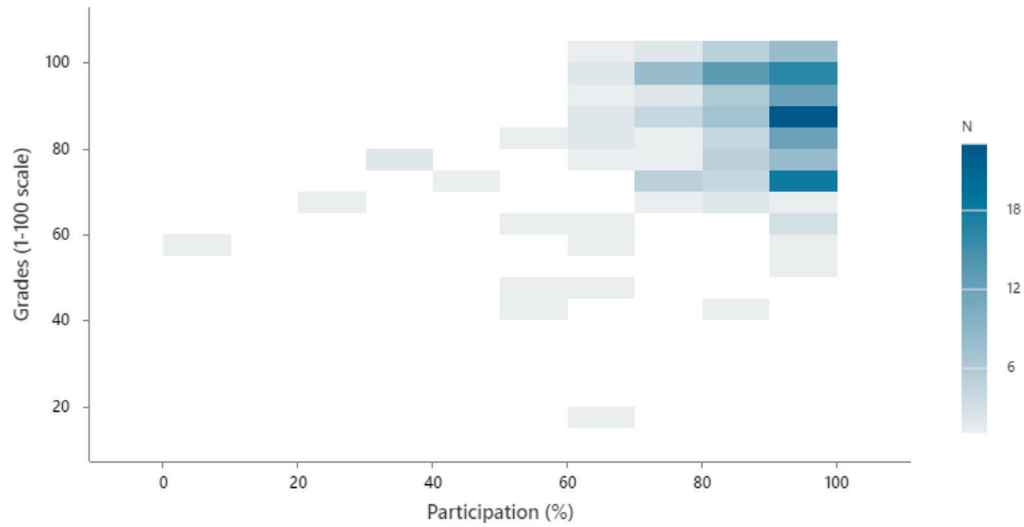

Figure 7. Binned Scatterplot of Grades vs. Participation. 118 data. The tendency is that more active participation on the interactive platform leads to higher grades.

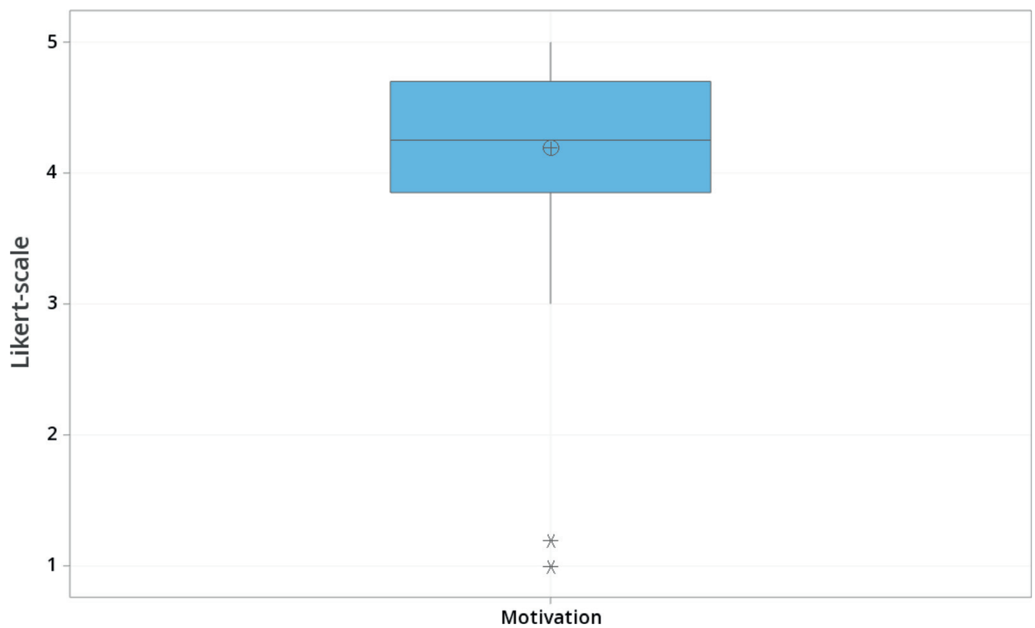

Figure 8. Boxplot of Motivation average through MAKE evaluation instrument. Likert scale: (5) Strongly agree, (4) Agree, (3) Undecided, (2) Disagree, (1) Strongly disagree. 91 participants. Dot (○) shows the average of each group and the asterisk (*) shows outliers. Average 4.2, Box (3.9, 4.7), Whiskers (3,5).

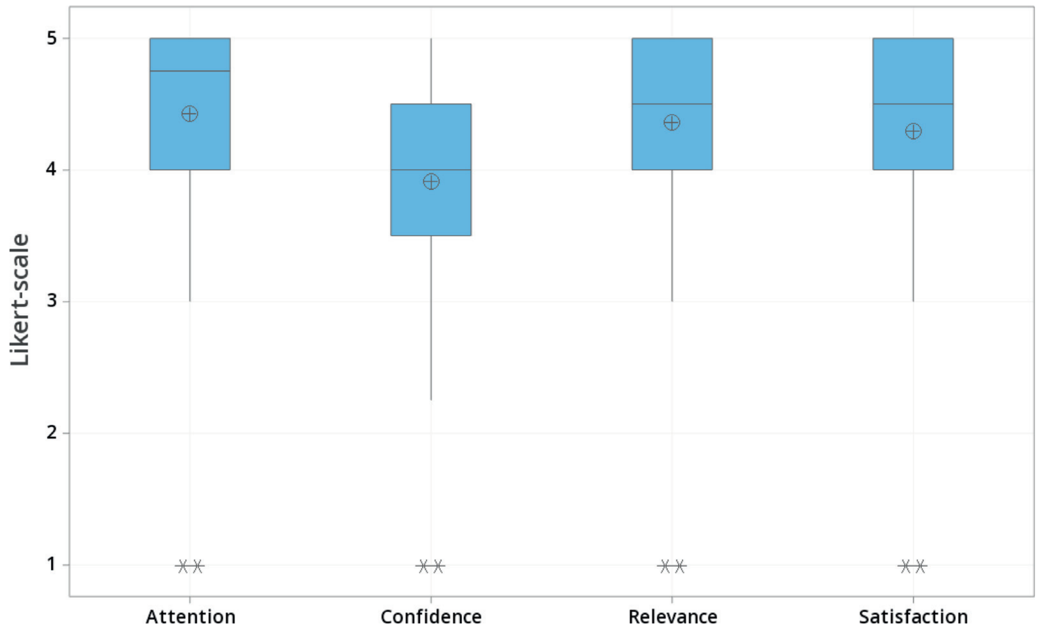

Figure 9. Boxplots of Motivation elements using the MAKE evaluation instrument. Likert scale: (5) Strongly agree, (4) Agree, (3) Undecided, (2) Disagree, (1) Strongly disagree. 91 participants. Dot (○) shows the average of each group and the asterisk (*) shows outliers. Average: Attention= 4.43, Box (4,5), Whiskers (3,5); Confidence= 3.92, Box (3.5,4.5), Whiskers (2.25,5); Relevance= 4.37, Box (4,5), Whiskers (3,5); Satisfaction= 4.3, Box (4,5), Whiskers (3,5).

For a better understanding of the motivation variable, Figure 9 presents the constructs that make up the motivation variable. It is observed that Attention, Relevance, and Satisfaction are elements whose average is greater than 4 and all the boxes and whiskers are above 3. For the Confidence construct, the average is 3.9, and the lower whisker reaches 2.25.

These results are evidence of the high motivation of the students when the class follows the ITIF methodology, with two outliers indicating the need for individual attention for those few participants who are less motivated. The Attention is particularly high, which could be a positive indicator of the effectiveness of the strategies used.

Students' Perception of the Utility of the Interactive Learning Platform

91 students answered the four questions related to their perception of the utility of the interactive learning platform, listed in Table II. The results are shown in Figure 10. For the elements of Attention, and Learning, the average is 4.4 and the boxes are between 4 and 5; for Learning the average

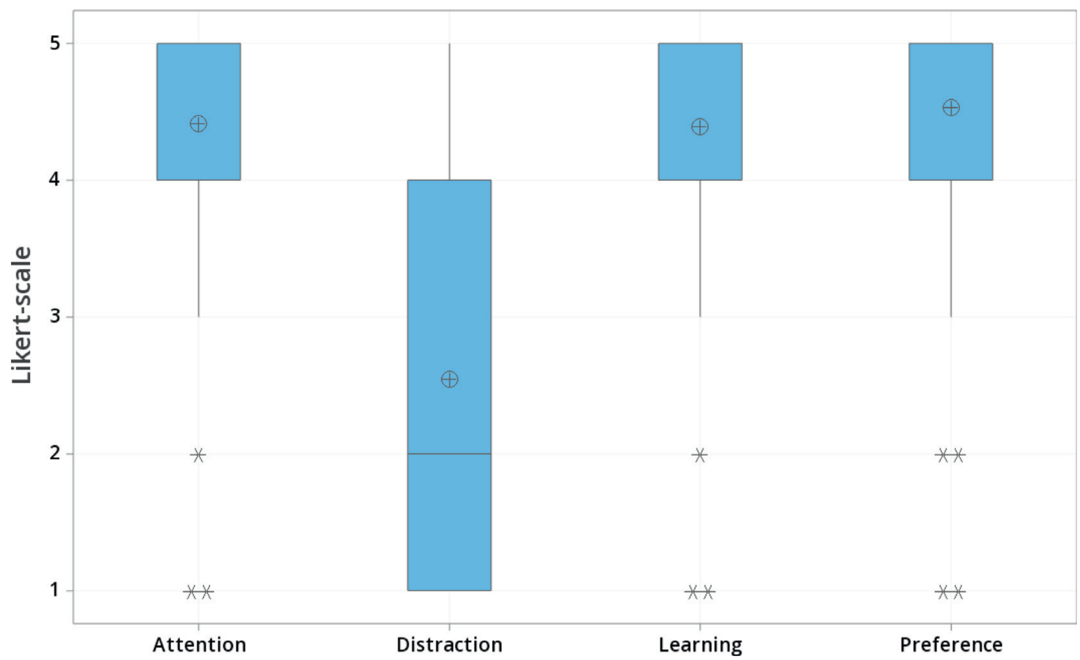

Figure 10. Students' perception of the utility of the interactive learning platform. Likert scale: (5) Strongly agree, (4) Agree, (3) Undecided, (2) Disagree, (1) Strongly disagree. 91 participants. Dot (○) shows the average of each group and the asterisk (*) shows outliers. Average: Attention= 4.4, Box (4,5), Whiskers (3,5); Distraction= 2.6, Box (1,4), Whiskers (1,5); Learning= 4.4, Box (4,5), Whiskers (3,5); Preference= 4.5, Box (4,5), Whiskers (3,5).

is 4.5 and the box is between 4 and 5, too, which talks about a high perception of the utility of the platform. For the Distraction element, the answers are widely dispersed around the 2.6 average; most of the students say the use of the platform doesn't distract them, but there is an important section of the population who perceive the platform as a distractor.

DISCUSSION

The study's findings suggest a positive relation between students' academic performance and class participation via an interactive learning platform when utilizing the ITIF methodology (Figure 7). The diagram shows that the upper right region has the highest density, indicating that students who participate more tend to achieve better grades. However, in other areas, there is variability, indicating that participation is not the sole factor influencing ratings. The trend observed in Figure 7 is consistent with previous studies that have shown that interactive platforms can improve student participation and engagement (Chen, Lambert and Guidry 2010).

The immediate feedback provided by the interactive platform used in the study plays a crucial role in student learning. Nicol and Macfarlane-Dick (2006) stressed that immediate feedback helps students identify and correct errors quickly, promoting more autonomous and deeper learning. The findings of this study confirm that students who received continuous, real-time feedback perceived their learning process in physics and mathematics concepts as better (Figure 10); specifically, according to the results of the MAKE instrument, students registered high levels of confidence in the content learned, recognized it as highly relevant and felt very satisfied with the class sessions (Figure 9). Confidence, relevance, and satisfaction were also enhanced by ITIF's Final Integration phase, which reviews the main contents at the end of each session. This phase is inspired by the PBL learning strategy, which according to Duch et al. (2001) improves students' ability to apply theoretical knowledge to practical situations. Tofade, Elsner, and Haines (2013) also support summative review at the end of classes as an effective strategy to consolidate learning and ensure retention of key concepts.

The implementation of the ITIF class methodology has shown elevated levels of student motivation, which is a crucial factor in academic performance (Figure 8). This result is consistent with the result of Banda & Nzabahimana (2023), where they show high levels of motivation in physics content using interactive simulations, and with the result of Poçan, Altay & Yaşaroğlu (2023) where high motivation is also observed when using educational technologies in mathematics content. The ITIF methodology has been proven effective in both physics and mathematics. It is based on an interactive platform that has appropriate elements for both types of content and each of the phases can be easily adapted for both physics and mathematics.

Finally, the positive perception of the students about the usefulness of the interactive platform is a finding that supports the ITIF methodology (Figure 10). The result obtained in this study exceeds the previous implementation presented in (Hernandez-Mena, et al. 2024). The averages of the variables increased: Attention increased from 4.15 to 4.40, Learning increased from 4.18 to 4.40 and Preference increased from 4.32 to 4.50 (Likert scale calibrated from 1 to 5); the increase is attributed to the fact that the use of the Nearpod platform was accompanied by the four phases of the methodology, which improved the perception of usefulness of the platform. It is worth mentioning that both the average and the dispersion of the Distraction variable also increased; this is an aspect that must be considered when using technological platforms that give the student access to distractions inherent to the Web.

The findings of this study demonstrate the potential of the ITIF methodology, supported by an interactive learning platform, to enhance student motivation and academic performance in engineering education. Beyond the studied institution, this approach can be adapted to various educational contexts by leveraging its structured phases, which are versatile enough to accommodate different engineering disciplines. For instance, the methodology's emphasis on immediate feedback and active participation can be particularly effective in subjects requiring complex problem-solving and concept application, such as classical mechanics, thermodynamics, differential, or integral calculus. Moreover, the integration of interactive platforms like Nearpod, Mentimeter, or Pear Deck allows educators to monitor and adapt their teaching strategies in real-time, fostering a more dynamic and student-centered learning environment. By implementing ITIF in diverse settings, institutions can promote higher engagement and better learning outcomes, aligning with modern pedagogical trends and the demands of engineering education globally.

CONCLUSIONS

The implementation of the ITIF methodology in first-year engineering courses has proven to be a highly effective strategy for maintaining elevated levels of motivation and improving students' academic performance in physics and mathematics. Our findings show a significant positive relationship between student participation through the interactive platform and their grades, suggesting that the integration of interactive educational technologies and structured teaching strategies can significantly enhance the teaching-learning process.

The ITIF methodology stands out due to its structured phases that provide continuous feedback and repeated review of key concepts, which are essential for consolidating student learning. This approach not only captures and sustains student motivation but also facilitates deeper understanding and retention of complex concepts, making it a valuable and innovative pedagogical practice in engineering education. In practice, educators can leverage the ITIF methodology to create more engaging and effective learning environments. The use of interactive platforms allows for real-time adaptation of teaching strategies based on student feedback and participation, fostering a more responsive and student-centered learning experience.

Future research could explore the application of the ITIF methodology in diverse educational settings beyond physics and mathematics, including various fields outside of engineering. Additionally, examining a broader range of subjects will help to further validate the methodology's effectiveness.

In conclusion, the ITIF methodology offers a robust framework for enhancing student motivation and academic success. We recommend educators and institutions consider adopting this approach to foster more dynamic and effective learning environments that meet the needs of today's students.

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