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Enhancing Flipped Classroom Mastery Learning using ZOOMRBT Apps with Fuzzy Delphi Method Verification

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ABSTRACT

The objective of this research is to investigate expert consensus on designing and developing ZOOMRBT apps for the purpose of enhancing students' mastery learning skills in a flipped classroom environment. This research employed a purposive sampling technique, selecting fourteen experts. The evaluation of flipped classroom deployment and lesson preparation was carried out using the fuzzy Delphi technique and data analysis involved the use of Triangular Fuzzy Numbers and Defuzzification. This research not only seeks to foster independent learners capable of addressing today's challenges but also aims to improve the quality of teaching and learning. In the flipped classroom setting, the ZOOMRBT mobile application is proposed as a model for mastery learning. Proficient instructors participated in this training and the online flipped classroom was carefully planned to integrate pre-class, in-class and post-class activities. The ZOOMRBT app was utilized during these sessions to create a cutting-edge learning environment. The results showed that all the experts unanimously reached a consensus of 100%. The approach of designing and developing ZOOMRBT to enhance mastery learning skills in flipped classroom settings was unanimously accepted by all the experts. The ongoing objective of this study is to assist educators in improving their pedagogical competence and their understanding of digital pedagogy, ultimately empowering students in Malaysian Boarding Schools to become more skilled learners.

1. Introduction

The proficiency of educators holds significant importance in the digital era. Teaching is a talent [16]. When it comes to skills, preparation, delivery and assessment are among the knowledge and abilities associated with specific fields that are frequently questioned.

Professional competences known as "digital pedagogy" call on educators to incorporate these skills into their teaching [27]. Assessment instruments that promote mastery and collaborative

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learning are part of this transformation, enabling teachers to teach more effectively and better monitor their students' educational progress [21]. Regrettably, the World Bank and UNESCO-UNEVOC have found that a lack of effective knowledge transfer pedagogical abilities often leads to vocational instructors in developing nations, particularly in Southeast Asia, falling short of meeting the expectations of the global workforce [28]. Incorporating Design and Technology disciplines into technology application aspects, for example, can transform TVET pedagogy and meet industry demands [5] while also sparking students' interests and making a significant impact [22]. As a result, the latest teaching strategies, such as flipped classrooms and hybrid learning, have been integrated into the curriculum. Consequently, teachers in Boarding Schools must play a more active role in assisting students in reaching their full potential. This involves developing their pedagogical skills, aligning the curriculum with their lessons, enhancing student mastery and boosting their confidence in using technology for academic purposes. Teachers' teaching abilities must undergo continuous development in creative pedagogy, especially in TVET domains like design and technology topics. Given that digital pedagogy is already an integral part of the education system, this research focuses on the creation and design of the ZOOMRBT application for teacher mastery learning. It is expected that the systematic development and design of the ZOOMRBT application will aid and encourage educators in the teaching and learning process, facilitating efficient knowledge transfer [1]. The development of the latest digital versions of the flipped classroom model's applications can support the nation's TVET policy and be recognized as a crucial component of the effective implementation of both traditional and online teaching and learning [2].

2. Methodology

This study employed the Fuzzy Delphi Technique (FDT) [8]. The decision to use this method was made with the goal of establishing expert consensus among teachers regarding the essential elements for creating ZOOMRBT apps for mastery learning in flipped classrooms. According to Hasim *et al.,* [14], FDT allows experts in a field to reach a consensus. The FDT method is preferred over the Delphi methodology due to its ability to handle the interview process more efficiently and cost-effectively. Furthermore, it enables a more systematic expression of expert viewpoints [7]. The Delphi approach, which involves expert panels to gather and compile data, has been used in expert studies for many years. However, it has limitations, including potential issues with data reliability and subjectivity. The Fuzzy Delphi approach has been employed to address these limitations by reducing the research duration and achieving a more objective consensus [10]. This technique utilizes fuzzy elements to reach an agreement in a single round and prioritize expert inputs. Triangular fuzzy numbers are used in this method and the defuzzification process plays a central role in achieving consensus.

In summary, the article provides valuable insights into the importance of technology-enhanced education, particularly within the context of the flipped classroom model [6]. However, some sections of the article could benefit from clearer organization and conciseness to enhance readability.

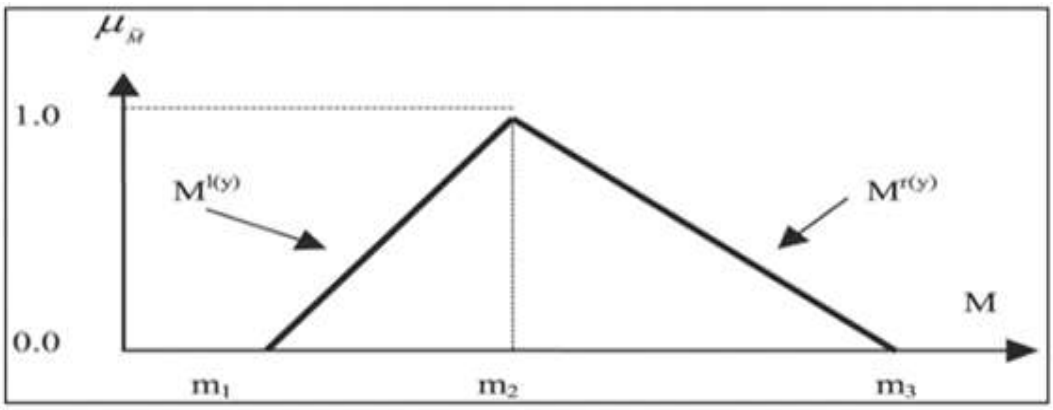

Fig. 1. The triangular number

In order to convert language variables into fuzzy numbers, the linguistic scale—which is the same as the Likert scale—utilizes a triangular fuzzy number [3]. A higher scale of linguistics enhances data accuracy, which is why the number of levels on the linguistic agreement scale should be an odd number (3, 5, 7...). In this study, we employ seven-point linguistic measures, as shown in Table 1.

Table 1
Fuzzy linguistic scale

Linguistic Variables	Likert Scale	Fuzzy Scale
Strongly disagree	1	(0.0,0.0,0.1)
Moderately disagree	2	(0.0,0.1,0.1)
Slightly disagree	3	(0.1,0.3,0.5)
Neutral	4	(0.3,0.5,0.7)
Slightly Agree	5	(0.5,0.7,0.9)
Moderately agree	6	(0.7,0.9,1.0)
Strongly agree	7	(0.9,1.0,1.0)

Defuzzification techniques are employed to determine the relative importance of each variable or sub-variable. This process is intended to assist researchers in identifying the significance of a variable level and the required sub-enablers. This ranking procedure will help in generating essential data based on expert opinions. There are three different formulas that can be used, including in Eqs. (1) to (3):

$$Amax = 1/3 * (a1 + am + a2) \quad (1)$$
$$Amax = 1/4 * (a1 + 2am + a2) \quad (2)$$
$$Amax = 1/6 * (a1 + 4am + a2) \quad (3)$$

2.1 Delphi Process

The Delphi-based research was divided into three stages: preparation, conduct and analysis, with a focus on prospective characteristics and recent advancements to complement and expand current Delphi research literature. The researcher's approach was sequential, involving consecutive interactions, data collection, distribution and application revisions at intervals. Beiderbeck *et al.,* [4] utilized the real-time Delphi technique, employing software that provided instant feedback to participants. Participants shared essential information on how to use ZOOMRBT applications and their engagement in mastery learning, while also offering insights based on their personal experiences [12]. The Delphi method encompasses an iterative and multistage process, controlled

feedback, the opportunity for individuals to revise their answers and a certain degree of anonymity [13]. The qualitative data gathered through open-ended questions was selected to illustrate how individuals construct their reality in interaction with their social context [11].

2.2 Participants

The researchers collaborated with boarding school instructors to conduct this study. The selected teacher has over ten years of classroom experience and has received awards for innovative use of educational technology at the federal level.

2.3 ZOOMRBT Apps for Education Development

Prototype development does not require computer coding language and generates unique applications for web or mobile devices. The ZOOMRBT app is an Android and iPad-based application platform that offers user-friendly features. Additionally, it enables users to collaborate and engage in real-time while working in teams to create accurate representations of final products. Consequently, it is an excellent platform for developing prototypes based on original concepts discovered through critical thinking to address real-world challenges. The following functions of the ZOOMRBT application have been created:

i. General: After uploading the ZOOMRBT icon, the ZOOMRBT application module typically contains 11 files, which include a teaching video, project gallery, instructor guide, class schedule, quiz, PBD Template, daily teaching plan, Form 1-3 Textbook and Teaching Plan template.
ii. Teaching Video: Instructors can customize teaching materials, covering electrical, electronic and mechatronic design subtopics, for students to watch during their pre-class preparation or during the students' available hours using the teaching video module provided by the researchers and SBP instructors.
iii. Project Gallery: Each project conducted in a class or workshop is documented and included as evidence in the Project Gallery folder. This serves as a resource for teachers or stakeholders when evaluating projects.
iv. Teacher's Guidance: The teacher's guidance is a classroom-based assessment document that includes teaching modules, assessment standards and assessment criteria. It serves as a reference point both during and before the teaching session.
v. Class Schedules: Class schedules are essential resources for teachers and students to manage their time effectively, both in and outside of the classroom.
vi. Quizziz: Quizziz offers a virtual quiz that can be taken during morning and evening prep sessions. Students find it easier to respond and teachers can track their progress over time to ensure mastery.
vii. PBD Template: The PBD template is part of the PBD assessment score filling and can be used as a guide by teachers and students for joint score verification. The Daily Teaching Plan template can be easily filled out by the teacher and the teacher's reflection can be added at the end of the lesson with ease and accuracy.
viii. Forms 1–3 Textbook: The Forms 1–3 RBT Textbook supports after-hours study and can be utilized for instruction in the first class. Malaysian Boarding Schools' instructors and students have access to real-time student performance data to support classroom activities and view comprehensive progress reports for each discussion group.

2.4 Data Analysis

The researcher examined coded data to identify common words, variable relationships, categories, themes, significant differences among subgroups and recurring patterns. These similarities and differences were used to make adjustments to the ZOOMRBT applications and the findings were collected and presented to the participants, along with a link to the second and third round of questions. The analysed data was then used to determine necessary modifications to the applications between rounds. Based on the data received from the first and second round questions, changes were made to the second and third rounds as required. If a high level of agreement was achieved on a specific topic and no further suggestions for improving that aspect of the application were provided, the question was either eliminated or modified for the subsequent round of questions. If responses indicated any confusion in questions, the questions might have been reworded for clarity in the following round or explanations were emailed to the participants along with the gathered data.

Data from the second and third round questions were collected and coded, managing using vVivo. Consensus can be defined in various ways depending on the study. For the purposes of this study, consensus is defined as 80% or more of the participants answering the same questions or agreeing on the same answers. Following the three rounds of interviews, informal follow-up discussions were conducted and recorded using a voice recorder. Themes were categorized and organized in nVivo after transcriptions were converted into Word documents. These conversations were not intended to collect additional data, but rather to clarify any questions the researcher may have had regarding open-ended responses, gather feedback from participants and provide closure and information to prepare a formal thank you for participation in the study. For the first round, data from Google Sheets were used to generate organized data files in nVivo. The text was reviewed and relevant comments necessary for providing feedback to participants and advising on improvements for the ZOOMRBT app were noted, forming the initial codes. The same approach was followed for the second and third rounds after participants received an overview of data collection from the previous round.

The data was then summarized in nVivo for ease of review. Participants were given the opportunity to explain why they rated a particular online resource based on their personal experiences with introduction and mentoring. Interviews were recorded and transcribed using the Voice Recorder and Audio Editor apps, then converted into Word documents. The researcher reviewed and listened to the interview transcripts for accuracy and made necessary revisions. Interview transcripts were categorized and compared for specific topics. The researcher extracted key statements from both interviews and organized these statements into meaningful units. Ultimately, a textural description was created to illustrate "how the phenomena were perceived," and a composite description was constructed to capture the "essence" [9]. The researcher then selected quotes to support data reports. To organize the data and conduct basic descriptive statistics, the nVivo program was employed.

3. Results

At the conclusion of the teaching session, all fourteen SBP instructors engaged in discussions regarding the flipped classroom approach, the development and design of ZOOMRBT apps and expert teacher consensus. Students were also invited to share their feedback on their classroom experience, the effectiveness of the apps and software employed, their comprehension of each course component and whether they would recommend the program to others.

3.1 ZOOMRBT Device Application in Flipped Classroom Mastery Learning

From the perspective of the ZOOMRBT device application platform, the group-focused interview questions primarily revolved around utility, ease of use and enjoyment. Based on the interview responses, it was discovered that the ZOOMRBT device application provides a comprehensive overview of all the learning needs of the flipped classroom model, including textbooks, quizzes, daily lesson plans and other resources that contribute to the development of a mastery learning strategy.

Most students found the Quizziz folder to be both enjoyable and helpful for mastering the material, as it presented challenges they had to overcome to answer each question. In terms of enjoyment, many noted that group discussions during the implementation of the PBD project were engaging and fun, leading to high levels of involvement. Similarly, they believe that using the ZOOMRBT app in conjunction with Tinkercad without coding is enjoyable due to its user-friendliness. They express their intention to continue using this platform to enhance their learning skills and create an enjoyable learning environment. Feedback was also collected about their prior knowledge. All respondents mentioned having experience with flipped classroom models, such as using iPads and Android devices, but not specifically with the ZOOMRBT application. However, the ZOOMRBT simulations with Tinkercad helped them understand the implementation of electrical, electronic and mechatronics projects in a more enjoyable manner. Overall, all respondents expressed satisfaction with this teaching method, with most of them indicating their willingness to recommend it to others.

Questions were asked about whether perceived utility, enjoyment and convenience contribute to improved learning outcomes. The analysis reveals that most interviewees found this online teaching method, which combines the flipped classroom model with the development of the ZOOMRBT application, to be highly engaging and effective for learning topics such as electrical design, electronics and mechatronics. Moreover, pre-class activities enabled them to reinforce the concepts taught during classes. Furthermore, the premium classes with SBP teachers enhanced their self-confidence and communication skills. Most of the interview results emphasized that the use of apps and participation in group discussions could improve knowledge sharing capabilities, ultimately enhancing learning outcomes in a straightforward, enjoyable and valuable manner.

3.2 ZOOMRBT Device Application Design and Development

An application software designed to operate on mobile devices, such as smartphones or tablet computers, is generally referred to as an app. Mobile applications usually offer features similar to those found on PCs. An instructional mobile app named "ZOOMRBT" was developed to bridge the gap between formal pedagogical education and informal forms of education that students encounter outside the classroom. The application's goal is to make teaching and learning Design and Technology subject concepts more interesting and enjoyable for both teachers and students. It aims to introduce fundamental ideas from the Design and Technology curriculum, including mechatronics and electric or electronic design, to students at Malaysian boarding schools. Students should be able to:

i. Effectively apply knowledge of fundamental theories in the field of design and technology.
ii. Use these theories to solve product-related problems.
iii. Explain how to improve product designs clearly.

The ZOOMRBT app can be used as a teaching tool by design and technology instructors, acting as a "guide on the side," or by students for self-directed learning. The application was created using an active, exploratory learning strategy in a multimedia setting, including access to hypermedia learning

content in the form of HTML pages, online content and interactive games [18]. Learners have the opportunity to think about and reflect on the concepts presented in the learning material through navigation within the application's environment. They can evaluate their understanding of these topics through the engaging and entertaining action of a mobile application [25].

The creation of instructional materials should be based on the concepts of instructional design theories, learning theories, models and media choices for educational purposes [26]. The process of designing for wireless mobile devices is challenging and complex, with no established standards for creating a useful and effective mobile application supported by research. The following factors were taken into consideration for the interface design in this study:

i. Flexibility
ii. Learning strategy
iii. Class infrastructure
iv. Educational technology

Several design principles for desktop programs were also utilized in this study, which are equally applicable to mobile learning settings, even though they were not explicitly designed for them. To create inclusive mobile learning resources, the applicability of most of these design concepts for inclusive online learning is enhanced. The user interface of a learning system encompasses how the system looks and feels, how users interact with it during learning and how the system responds to user engagement [19]. The user interface was designed to be straightforward, explicit and intuitive and the navigation within the application was kept as simple as possible to avoid requiring students to read specific written instructions or possess specialized technical knowledge. It was intended for students to be able to explore the application's environment as soon as they logged in, giving them the opportunity to find what they need [20].

The platform design and system design of the ZOOMRBT app include several interactive elements, such as course materials, educational videos, self-assessment projects, quizzes, connections, portfolios, games, chat and feedback. The instructional content is comprised of texts, pictures and interactive animations. Users of Apple and Android operating systems can access the free web-based application, which offers modules and components for both platforms. To fully access the learning activities, users must download and install the ZOOMRBT application on their mobile devices. The interfaces in the following table were created based on the description of the ZOOMRBT modules provided in Figure 2.

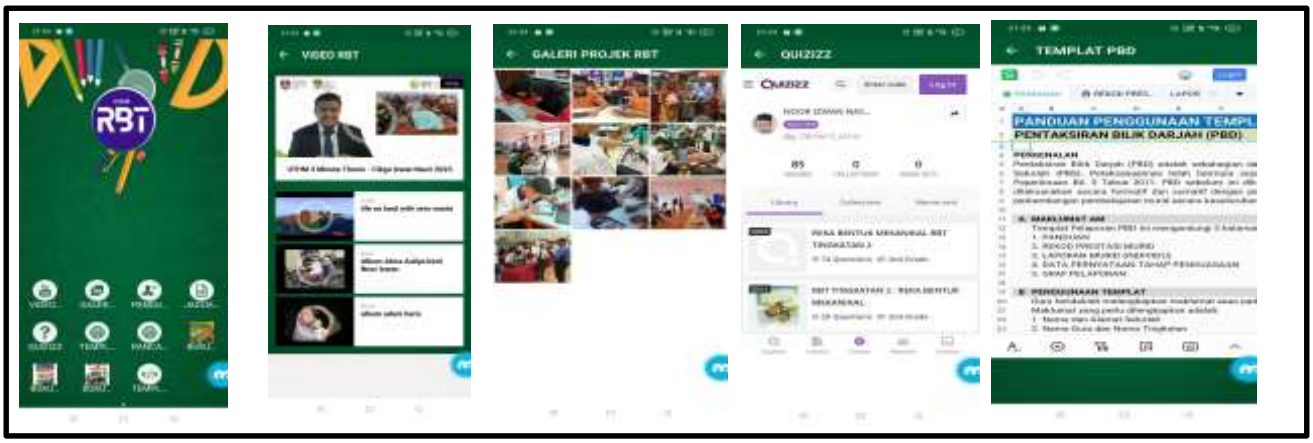

Fig. 2. System design of ZOOMRBT apps

3.3 Evaluation of Expertise

One of the requirements for FDM analysis is the threshold value determined from expert consensus. The threshold value must be lower than or equal to 0.2 (d ≤ 0.2). Table 2 shows the threshold value (d) for the instrument related to the design and development of the application, involving 14 experts.

Table 2
Evaluation of application design and development

Decision	Item 1	Item 2	Item 3	Item 4
Expert Teacher 1	0.0165	0.00825	0.00825	0
Expert Teacher 2	0.13197	0.12372	0.10722	0
Expert Teacher 3	0.09897	0.10722	0.12372	0
Expert Teacher 4	0.0165	0.00825	0.00825	0
Expert Teacher 5	0.0165	0.00825	0.00825	0
Expert Teacher 6	0.0165	0.00825	0.00825	0
Expert Teacher 7	0.0165	0.00825	0.00825	0.11547
Expert Teacher 8	0.0165	0.00825	0.00825	0.11547
Expert Teacher 9	0.0165	0.00825	0.00825	0
Expert Teacher 10	0.0165	0.00825	0.22269	0
Expert Teacher 11	0.09897	0.10722	0.12372	0.11547
Expert Teacher 12	0.0165	0.00825	0.00825	0.11547
Expert Teacher 13	0.0165	0.00825	0.00825	0
Expert Teacher 14	0.09897	0.00825	0.00825	0
	Item1	Itemc2	Itemc3	Itemc4
Value D of each item	0.04242	0.03064	0.04713	0.03299
Threshold Value (d) Construct				0.0383
Item < 0.2	14	14	13	14
Expert Teacher Agreement Percentage (%)	100%	100%	92%	100%
Average of % consensus				98
Defuzzification (Alpha Cut)	0.62857	0.61429	0.58571	0.6
Ranking Position	1	2	4	3
Status	Accepted	Accepted	Accepted	Accepted

Table 2 shows the construct for value (d) is 0.04, which is less than (d ≤ 0.2). The appropriate construct according to the Fuzzy Delphi procedure is indicated by the value of the (d) construct. However, the construct's value (d) is 0.113. Therefore, in accordance with the Fuzzy qualifying criteria, when the value of d < 0.2, four elements in E1 (d) = 0.056, E2 (d) = 0.042, E3 (d) = 0.047 and

E4 (d) = 0.045 are approved in the application and design development construct. As a result, the expert consensus percentage—that is, the percentage value requiring more than 75% expert consensus for each element—must also meet the fuzzy qualifying condition.

The defuzzification score shows how each element was ranked according to the consensus of experts. For every element, the fuzzy score (A) analysis ranges from 0.042 to 0.056. However, the defuzzification process value also indicates that each of the four items has an α-cut value of less than 0.5. The components that meet the requirements of the Fuzzy Delphi procedure are E1 and E1 = 0.571, E2 = 0.628, E3 = 0.657 and E4 = 0.614. These are the four elements that the expert panels have approved, along with the value of the α-cut. As a result, the ranking process will replace the defuzzification procedure. The goal of this procedure is to rank the aspects that are acceptable in relation to the defuzzification process.

According to the results, item 3 is ranked number one (1), item two is ranked number two (2), item four is ranked number three (3) and item one is ranked number four (4) as the final ranking for the various elements of the application design and development process.

4. Discussion and Conclusion

This study is consistent with the strategy of Mariappan *et al.,* [23], who discovered that the selection of appropriate aspects must be emphasised in order to coincide with the students' individual degrees of practice. In addition to creating a user-friendly application, the creation and usage analysis of the ZOOMRBT apps also provides added value for the users themselves, i.e., instructors and students in the modified flipped classroom paradigm. According to empirical research, design and development requirements analysis help instructors construct learning applications in a more comprehensive manner. It is also used to determine the extent of technology required to support teaching and learning. The findings are expected to assist researchers and developers in formulating more thorough assessment questions for Design and Technology disciplines that include project-based assessments or inquiries that involve higher-order thinking skills [17]. Teachers of Design and Technology disciplines also responded favourably to the survey, with the majority of them inquiring about how to create this type of Android application using the Android Package.

The overall positive assessment of this study's building blocks is that students enjoy using the ZOOMRBT app's visual elements, questions, sound effects, token incentives and intriguing symbols [15]. The development of the ZOOMRBT apps in the flipped classroom model also highlights the shift in priorities for valuable elements before and after evaluation by teachers, i.e., the transformation after applying the Fuzzy Delphi technique. The Defuzzification score demonstrates that the study has contributed to the development of a new model, emphasizing that contents are initially created to gather student feedback, followed by design and development. This approach allows for the assessment and ranking of other aspects, such as application design, verification, maintenance and deployment, with the hope that the value of this defuzzication can lead to more useful research in the future.

5. Recommendation for Practice

The implementation of these ZOOMRBT applications in all Malaysian Boarding Schools' career and technology centres could benefit both new and experienced teachers. If the ZOOMRBT applications were used to support flipped classroom model teachers, it could have a positive impact on students' mastery learning [24]. The researchers aim to distribute this resource to instructors

across the state, as well as to certify alternatively credentialed technology teachers. Providing resources to all instructors could bridge the current gap between urban and rural schools. Teachers from similar programs of study can interact, ask questions and exchange resources through this expertise exchange. The researcher will also continue to update and publish the apps to ensure the resource's long-term viability, with the goal of having an organization take over the current website or create a similar resource.

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