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# The design of game-based learning and learning analytics

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**ABSTRACT**

Game-based learning has received increasing attention in recent years as it could help improve pupils' motivation, self-efficacy, and achievement. Technological innovations like learning analytics (LA) and GBL offer pedagogical support for teachers. GBL could significantly support pupils' learning as a learning approach compared to conventional approaches. Therefore, there is a need to elevate " teachers' level of knowledge on the impact of GBL. In the meantime, LA could be used to collect, analyze, and report data on the impact of GBL on pupils' learning performance. In this light, GBL applications have been developed to facilitate the use of LA for teaching and learning. This paper describes the design of GBL with LA integration for teaching mathematics in primary schools. It documents the construction of the GBL and AL app, which is grounded on the Dick, Carey, and Carey Model and the theory of constructivism. In addition, the cognitive load theory was applied to ensure that the application accommodates pupils' cognitive load. This study also validated the design of the GBL, and it was found to be relevant and engaging.

Keywords: Game-based learning, mathematics, analytics, technology, education

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## 1. INTRODUCTION

Game-based learning (GBL) is an approach that combines the elements of play with learning objectives (Nadolny et al., 2020) to improve teaching and learning and create a meaningful learning environment to encourage knowledge acquisition. Studies have found that GBL is useful for pupils with learning difficulties (Niemelä et al., 2020). In this light, the application of game elements needs to include fun, interactive features that could motivate pupils to learn (Marcial et al., 2021) and encourage competitiveness. Pupils' engagement in GBL activities could be enhanced when the competitive element is supported by the collaborative element (Zou et al., 2021). Thus, teachers should ensure that the learning elements in GBL, specifically the game content, question format, and teaching strategies, can encourage pupil involvement in the learning process (Cheung & Ng, 2021) to increase their knowledge. This could ensure that GBL's application provides a meaningful learning experience and develop pupils' cognitive skills to solve heuristic and analogical problems.

GBL applications use artificial intelligence to record learning activities throughout the game session, and these data could be utilized optimally to improve learning. An efficient GBL platform allows teachers to collect, analyze, and utilize its usage data to better understand pupils' learning processes (Niemelä et al., 2020). However, teachers' use of GBL as a teaching aid is still limited. As a result, data such as time, score, and usage status data from GBL applications have not been well utilized. The failure to utilize such data hindered teachers from obtaining meaningful and useful information about pupils' learning (Hue et al., 2015). The lack of proper data interpretation and analysis causes the failure to identify the problems pupils face and create challenges in achieving the pupils' expected performance. Subsequently, teachers fail to understand pupils' learning situations, identify pupils with dropout risks and implement interventions (Hussain et al., 2019). The learning analytics (LA) approach can be applied because of its ability to collect, analyze, and report in-depth data on pupils' learning situations (Ebner & Pronegg, 2015).

This study conducted a systematic literature review (SLR) using the PRISMA method (Preferred Reporting Items for Systematic reviews and Meta-Analyses). Articles and past works on the relevant issues were derived from Scopus and Web of Science. As shown in Figure 1, the findings show that applying GBL and LA approaches has significant benefits for teachers and learners. The review also showed that most studies focusing on LA and Mathematics focused on using cognitive Tutor (special software materials for research needs) in learning. In contrast, other studies examined the use of MOOCs and LMS. Another finding is that studies focused more on learning at the university level than at school.

**Figure 1**

*Flowchart of the study process (Adapted from Moher et al. 2009)*

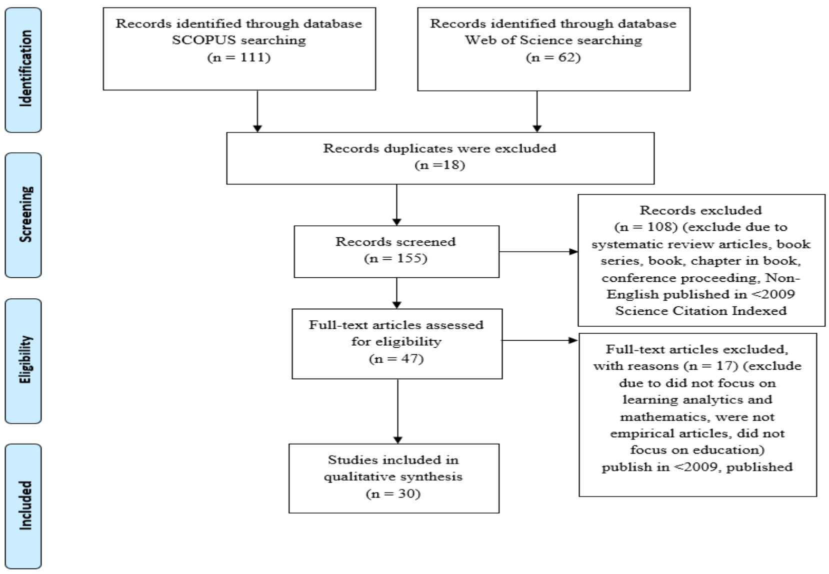


**Table 1**

*Research context for studies on LA and Mathematics*

| Research Context | Author (s)/ Year) | Number of Articles |
|---|---|---|
| MOOC | (de Kock & Harskamp 2016; Hadioui et al. 2017; D. Kim et al. 2018; Quinn et al. 2015; Ruipérez-valiente et al. 2015; Xing et al. 2017) | 6 |
| LMS | (Cohen 2017; Hue et al. 2015; San Pedro et al. 2017; Teasley 2017) | 4 |
| Cognitive Tutor | (Chu et al. 2017; Dani & Nasser 2016; Duzhin & Gustafsson 2018; Gal et al. 2018; D. R. Kim et al. 2016; Molenaar & Knoop-van Campen 2018; Román-González et al. 2018; Romero-Zaldivar et al. 2012; San Pedro et al. 2017; Smith et al. 2016; Tomkin et al. 2018; Xing, Guo, et al. 2015; Xing, Wadholm, et al. 2015) | 13 |
| Game-Based Learning | (Kickmeier-Rust, Hillemann, & Albert, 2014) | 1 |

The review found a lack of studies examining the use of the GBL approach with LA at the primary school level. Hence, this study developed the 'Prediction Jumping Mathematics (P-JMat)' game application that can be used for teaching mathematics in primary school. This paper describes the design of GBL with LA for primary school pupils.

## 2. BACKGROUND OF THE STUDY

The paper outlines the development of a learning material that combines GBL and LA elements for Mathematics learning. PJ-MAT is a mobile-based and computer-based application. It can run on iOS and Android operating systems. This application is a product from the author's initial research, "the Development and Effectiveness of Prediction Jumping Mathematics (P-JMAT) Application on Motivation, Self-efficacy, and Primary School Pupil Achievement for Basic Mathematical Operation". The application incorporates GBL and LA to narrow the learning gap between urban and rural pupils. This project is a collaboration effort between the centre of innovation in teaching and learning, Universiti Kebangsaan Malaysia, and the Ministry of Education.

### 2.0 Learning Goal and Outcomes

Experts in the education field were consulted to validate the P-JMat application. It can fill the gaps of existing learning applications which designers mostly developed without educational backgrounds. This situation results in low-quality GBL applications in the market and their failure to improve pupils' performance (Hussain, Tan & Idris, 2014).

GBL is a game-based application to help pupils achieve the set learning objectives. It focuses on achieving learning objectives rather than gaining rewards. GBL promotes a pupil-centred learning process that encourages pupils to seek knowledge, develop skills, and cultivate positive values through games created specifically for educational purposes. Meanwhile, LA allows a systematic data management, collection, and analysis process to d to anticipate pupils' achievement in Mathematics.

Thus, this study collected the data on usage duration, visitor status, and scores from the P-JMat application using an AP application. In terms of usage duration, pupils were asked to record the time they spent using the P-JMat application, while the data on visitor status comprises the frequency of pupils logging in to the P-JMat application and the score data refer to the scores obtained by pupils each time they use the application.

2.1 Why Game-based Learning and Learning Analytics?

GBL helps improve the quality of the Mathematics teaching and learning process. It provides a pupil-centred learning platform to help pupils achieve learning objectives parallel to the curriculum requirements (Farber, 2015). As a pupil-centred learning platform, GBL creates a learning environment that can encourage pupils to seek knowledge, develop skills, and cultivate positive values through games. The application of game elements in learning can increase pupils' motivation and positively impact pupils' achievement (Ylinen et al., 2021). GBL also encourages creative thinking in Mathematics problem-solving. Hence, the adoption of GBL in teaching and learning could help pupils develop critical and creative thinking (Tokac et al., 2019).

Another advantage is that GBL helps develop pupils' competencies and self-efficacy (Eseryel et al., 2014; Wu, Richards & Saw, 2014). Brezovszky et al. (2019) showed that adopting the GBL approach has successfully improved pupils' mathematics grades. The study found that the GBL-based Number Navigation Game (NNG) application improved pupils arithmetic skills and knowledge while providing a flexible and practical teaching tool.

GBL also exerts a strong learning effect by indirectly encouraging pupils to learn a Mathematics concept (Tokac et al., 2019) and practice basic Mathematics skills (Okur & Aygenc, 2018). The gaming element in learning can encourage pupils to apply the basic Mathematics concepts, reading skills and problem-solving skills to ensure that the given task can be completed. As a result, GBL impacts pupil motivation to learn and improves pupils' mathematics achievement (Bertram, 2020; Byun & Joung, 2018; Fuster-Guilló et al., 2019).

In the meantime, the varied data available have impacted our world today, including the field of education, which has also evolved by leveraging big data. In education, the goal is to effectively understand and improve the teaching and learning process. Thus, the analytical approach to learning (LA) could be applied in education to facilitate the process of collecting, measuring, analyzing, and reporting related pupils in its context to understand and optimize the teaching and learning process (Oyerinde 2017; Siemens & Baker, 2012; Vladimir et al., 2019).

The application of LA in the teaching and learning process has become a backbone in teaching and learning during the Covid-19 pandemic. The Covid-19 pandemic has changed the norms of human life worldwide and has resulted in many schools being closed and teaching and learning processes not being implemented. According to a report from UNESCO, UNICEF, and the World Bank, in October 2020, 1.5 billion pupils worldwide were affected by the Covid-19 pandemic as schools were forced to close as they became the epi-center of covid-19 infections.

Many initiatives have been implemented to prevent pupils from missing out on learning, especially in learning Mathematics during the movement restriction around the world, as Mathematics is a challenging subject. Many pupils perceive Mathematics as a difficult and uninteresting subject (Dele-Ajayi et al., 2019; Lai & Hwang, 2016; Tshewang, Chandra & Yeh, 2017). Consequently, neglecting mathematics over a long period can lead to dropouts, and teachers have strived to continue their teaching and learning process online and print learning materials for pupils at home. Even after the pandemic, teachers should expose pupils to varied learning methods parallel to their cognitive development (Ingram et al., 2016).

However, there are concerns about the effectiveness of teachers' teaching approaches, especially during the pandemic. The lack of face-to-face learning made it difficult for teachers to monitor pupils' performance, and they were not able to provide effective instructions. This challenging situation calls for teachers to adopt LA in analyzing data about pupils' learning. LA provides valuable information to teachers to improve the quality of teaching, helps teachers reflect on the implementation of the teaching and learning process, and allows them to use data to provide accurate feedback to pupils (Oyerinde, 2017). In this sense, the application of LA in the teaching and learning process will benefit the application of ICT with the opportunity to serve human priorities, allowing better human-to-human interaction across the tyranny of distance and time zones (Brown, 2020).

The main goal of LA in the teaching and learning process is to utilize the teaching and learning process data to support the decision-making process in education. The application of LA in education helps build an understanding of the whole teaching and learning process to inform decisions made. The application of LA enables teachers to monitor and predict pupil performance, detect issues during the teaching and learning process and plan interventions to help struggling pupils. According to Orgaz et al. (2016), LA application has many benefits for teachers as a data-driven approach that could guide decisions to improve the teaching and learning processes. Furthermore, LA can help analyze data to design a predictive model that can be adapted to educational data and facilitate the application of simple technology devices to process data for helping to improve the quality of education. Therefore, LA is a critical aspect of today's education as it could ensure that the teaching and learning process is in line with the changing needs of the education system.

LA allows teachers to predict pupils' achievement (Hue et al., 2015) and improve pupils' mathematics achievement (Lu et al., 2018). Such prediction helps teachers take proactive steps to improve pupils' mastery of learning. In this regard, the effectiveness of the initial steps implemented by teachers can significantly impact pupils' achievement. In addition, the predicted results can encourage pupils at risk of dropping out or underperforming to reflect on the learning strategies they practise (Huang & Fang, 2013). It can also facilitate teachers' reflection on teaching methods, and pupils can evaluate the learning that has been applied and whether it is effective. This could improve the teaching and learning process over time to ensure that learning objectives are achieved, ensure gradual improvement of pupils' achievement, and reduce the risk of pupils dropping out. The literature review showed that previous researchers had applied LA by utilizing specific data, as summarized in Table 2 below.

**Table 2**

*Previous LA applications*

| Researcher | Purpose | Data Type |
|---|---|---|
| Kim, Hue & Shin (2016) | Anticipate and provide appropriate instruction | Visitor status<br>Page views<br>Time gap between visits |
| Dani (2016) | Determining pupils' academic achievement | Login data<br>Log data of topics studied<br>Controlled topic data |
| Romero & Ventura (2010) | Identify pupils' behaviour patterns and anticipate pupils' achievement | Score data<br>Final grade data<br>Learning outcome data |
| Roman, Perez, Moreno & Robles (2018) | Detecting computing talent | Usage time data |

Recent studies have used LA to predict pupils' achievement; hence, the types of data for certain variables need to be identified to improve the accuracy of the prediction. Data set with a particular variable can increase the accuracy of the correlation value in the prediction. However, having different variable data may not help improve the prediction accuracy (Huang & Fang, 2013). Therefore, this study found several data variables that help predict pupils' achievement. These data include usage duration (Hue et al., 2015; Román-González et al., 2018), visitor status data (Chu et al., 2017; Cohen, 2017; Dani & Nasser, 2016; Kim et al., 2018; Kim et al., 2016), and score data (Kim et al., 2016; Romero-Zaldivar et al., 2012; Tomkin et al., 2018). In this study, data on duration of use were obtained from the time the pupils spent using the P-JMat application. The visitor status data are based on the frequency of pupils logging in to the P-JMat application, while the data on score comprise marks obtained by pupils each time they use the application.

## 3. THE INSTRUCTIONAL DESIGN

The P-JMat application fills the gaps in learning models integrating GBL and LA. Dick, Carey, and Carey's (2015) model was selected as the foundation for app development as it is one of the most basic and comprehensive instructional design models. It is also suitable for the teaching and learning process in a formal environment. The implementation phase of this model is also less complex and easier to follow. Dick, Carey, and Carey's (2015) model emphasizes that reviewing teaching materials at each level prevents researchers from making mistakes and making corrections at the last minute. This instructional design model is also detailed, structured, and has an organized, easy-to-understand process sequence. The researcher believes that the use of the model in the development phase is time and cost-efficient.

The findings of P-JMat are described based on the 10 steps in Dick, Carey, and Carey's (2015) design model. The model is divided into four main phases, (1) analysis phase (needs analysis, teaching analysis, learning analysis), (2) design phase (writing objectives and construction of assessment instruments), (3) development phase (building strategies, selecting and constructing teaching materials), and (4) evaluation phase (constructing and implementing formative and summative assessments).

### 3.1 The Analysis Phase

The needs analysis of the study involved the evaluation of teaching and learning, which was conducted with several stakeholders. The analysis phase is guided by the Forrester Problem Analysis Method principles, consisting of problem definition, evidence, impacts, causes, and recommendations (Gonsenhauser, 2017). The researcher conducted an initial analysis based on the literature review and found that pupils are burdened with current learning approaches and are easily bored. In addition, some pupils consider education in schools to be irrelevant, troublesome, and boring (Dele-Ajayi et al., 2019) due to the influence of technology that makes knowledge accessible from their fingertips. The level of pupils' motivation toward learning Mathematics is also declining due to teachers' use of drilling in teaching and learning Mathematics and pupils' perception that Mathematics is difficult and uninteresting (Dele-Ajayi et al., 2019; Lai & Hwang, 2016; Tshewang, Chandra & Yeh, 2017). Therefore, teaching and learniMathematics in schools should emphasize the application of technology in the classroom (Eseryel et al., 2015; Okur & Aygenc, 2018). Applying the latest technology in the teaching and learning process will change the passive teaching and learning environment based on knowledge, critical thinking, and creativity. Therefore, the GBL approach has the potential to make the learning process more engaging and effective.

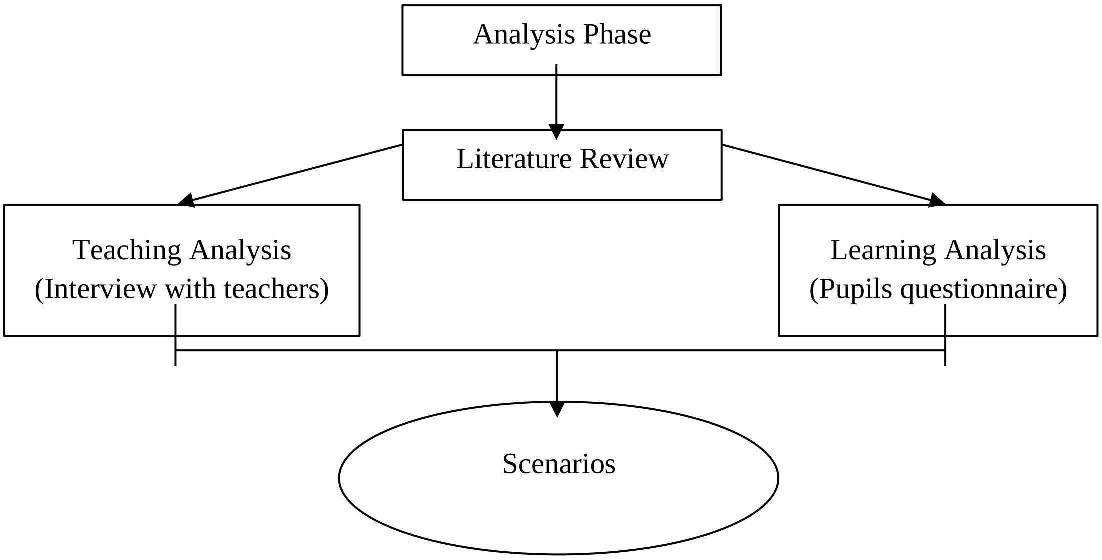
The learning analysis involved structured interviews with five primary school Mathematics teacher with more than 5 years of experience teaching Year 3 KSSR Mathematics. Teachers with more than five years of teaching experience from different schools were selected as informants. These sampling criteria were set to ensure that responses were received from experienced samples (Merriam & Tisdell, 2016). The interview data were then analyzed to obtain the common themes

The next phase is the learning analysis phase, involving 32 year 3 pupils. The number of pupils for this learning analysis was sufficient because they could provide adequate information related to learning

(Creswell & Creswell, 2018). A questionnaire was administered to these pupils to probe their perceptions of teaching and learning Mathematics. This process is illustrated in Figure 2.

**Figure 2**

*Analysis Phase*




The interviews revealed that while most teachers agreed that applying a game-based learning approach can increase pupils' motivation and participation in learning, teachers often use the conventional chalk and talk teaching method. The teacher will explain a topic in front of the class, and the pupils will do some exercises as practice. This finding is in line with the literature review. It indicates that teachers are still teaching using conventional methods even though the current generation of pupils tend to prefer digital tools as learning materials and enjoy game-based learning (Steinmaurer, Pirker & Gutl, 2020).

The learning analysis showed that 93.75% of the pupils stated that the sub-topic of the division is the most difficult skill for pupils to master. In comparison, 87.5% stated that the sub-topic of multiplication is a difficult skill to master in the topic of Basic Mathematical Operations. The findings also reported that 90.53% of pupils shared that they like to learn Mathematics using modern technological devices such as smartphones and laptops, and 98.88% of pupils like to learn Mathematics using game-based applications.

3.2 The Design Phase

The study design phase includes setting the objective and developing the research instrument construction step. Setting the objective is an important part of P-JMat application development. The setting of objectives is based on the analysis of teaching that has been done. This could determine the skills pupils need to learn and the setting of success criteria (Dick, Carey & Carey, 2015). Therefore, the learning objective with the application of P-JMat is to determine the effect of P-JMat on pupils' motivation, self-efficacy, and achievement in Mathematics, specifically in the Basic Mathematical Operations. In addition, the application of P-JMat can also predict pupils' achievement in Basic Mathematical Operations.

In the meantime, the evaluation instrument should be in line with the learning objectives and linked to the learning objectives' skills (Dick, Carey & Carey, 2015). The instrument should include items that measure the objectives that have been set. In this regard, the P-JMat provides an evaluation checklist to help teachers could evaluate technical and content aspects of the P-Jmat and their relevance to the learning objectives.

3.3 The Development Stage

A systematic literature review (SLR) was conducted to determine the teaching strategy highlighted in the P-JMat application. The researcher searched two main databases, SCOPUS and Web of Science (WoS) to retrieve relevant literature, particularly journal articles. This systematic literature review (SLR) was guided by PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyzes). This SLR analysis shows the importance of applying learning analytics (LA) in Mathematics learning. The application of AP in the learning of Mathematics could help improve the quality of teaching with the potential to reflect the development of pupils' learning. AP also allows teachers to predict pupils' achievement and prevent dropouts.

The SLR findings also showed that GBL emphasizes the use of technology to make the learning process more effective and meaningful (Okur & Aygenc, 2017; Miller, 2015). In the meantime, LA is an approach that can be applied while GBL is employed in the teaching and learning of Mathematics. GBL also contributes significantly to pupils' learning. It encourages pupils to learn a Mathematical concept directly and indirectly (Tokac et al., 2019) and develop strong basic Mathematics skills (Okur & Aygenc, 2018). As there are still limited studies that combine the AP and GBL approaches, the AP and GBL approaches should be applied to determine their effectiveness in helping to improve pupils' mastery of Mathematic skills.

In addition, the development of the P-JMat application is based on teaching and learning theory to ensure that pupils are highly motivated, possess self-efficacy, and perform well in Mathematics. Two learning theories were used to develop this P-JMat application, the cognitive load theory (Sweller et al., 1998) and the constructivism theory (Piaget, 1980).

Based on the cognitive load theory (Sweller et al., 1998), the researcher considered factors influencing pupils' cognitive load during the development of the P-JMat application. A good and effective learning process occurs when the learning materials match the pupil's cognitive ability (Van Merrieboer & Sweller, 2005). The P-JMat application also emphasizes sequencing the learning information according to the cognitive needs of pupils. This is important to ensure pupils apply their cognitive resources more effectively. In addition, the actions and things that need to be done by pupils while using the P-JMat application are minimized to ease pupils' cognitive burden. As a result, the contents and skills presented via the P-JMat application could be easily embedded into pupils' working memory while playing the game to support effective learning processes. The criteria and actions based on the cognitive load theory (Sweller et al., 1998) are shown in Table 3.

**Table 3**

*The criteria and actions related to the cognitive load theory (Sweller et al. 1998)*

| Theory | Criteria | Action |
|---|---|---|
| Cognitive Load<br>(Sweller et al., 1998) | Game instructions | ✓ Setting the minimum avatar function (walking and jumping) |
| | Compilation of information | ✓ Clear content description<br>✓ Minimize text so that instructions are easy to understand<br>✓ Combining text and |

| | | |
|---|---|---|
| | | graphics to avoid repetitive information |
| | Execution actions in the application | ✓ Minimal text and graphics<br>✓ Arrangement of pictures and words nearby<br>✓ Arrangement of pictures and related words simultaneously<br>✓ Minimal combination of animation and background |

The Constructivist Theory (Piaget, 1980) guides P-JMat application to provide self-directed learning to provide a meaningful learning experience for pupils. Integrating this theory with P-JMat could encourage pupils to learn new knowledge as they relate their existing knowledge with new knowledge independently and in a fun, meaningful way. The criteria and actions related to Piaget's (1980) Constructivist Theory are summarised in Table 4.

**Table 4**

*The criteria and behaviours based on Piaget's (1980) Constructivist Theory*

| Theory | Criteria | Action |
|---|---|---|
| Constructivist (Piaget, 1980) | Self-directed learning environment | ✓ Autonomy to pupils for access to the applications<br>✓ Easy and fast access to the application<br>✓ Fast and accurate feedback process |
| | In-app actions | ✓ Slow forward in learning |

The P-JMat application presents educational content through games and drills through self-directed learning methods. This strategy allows pupils to learn meaningfully and independently while teachers take on the role of mentors. In this regard, the P-JMat application use scoring strategies, fantasy, and adventure.

The P-JMat application features an instant feedback function responding to pupils' learning behaviours. This feature helps motivate pupils and encourages them to work toward the next level. This immediate response allows pupils to find out which mistakes have been made. The setting of this instant feedback function is an important function that distinguishes between game-based learning and gamification. Feedback is an important factor in learning and has a huge impact on GBL (Yang & Lu, 2021). Setting up instant feedback in the P-JMat app can help motivate pupils to move up to the next level. The application of GBL in the P-JMat application allows pupils to do exercises independently while playing, perform many questioning and answering activities and receive a display of learning progress and reinforcement of positive comments throughout learning so that pupils could learn independently without being afraid of making mistakes.

Furthermore, constant feedback could ensure effective learning. The feedback function in the P-JMat application is divided into two, feedback for correct answers and feedback for incorrect answers. Feedback for the correct answers includes encouragement words such as 'Good Job' while the wrong answer feedback requires pupils to repeat the task until they can complete it accurately.

The P-Jmat includes an adventure-based game where pupils are required to complete different missions according to the storyline to achieve the objective. The players were also given an avatar of a cub who wanted to return to a castle. A player will move the avatar character (cub) through the landscapes by walking, jumping, and dodging obstacles. They will get scores as they progress and answer the practice questions throughout the adventure. Users of the P-JMat application will go through the interface display, the split space display, and the game start display.

The interface is the first element players will encounter when entering the P-JMat application, creating the first impression about the game. After pressing the "play" button, the player will see the split space display. The split space display features the "levels" that pupils have to go through in the P-JMat application. There are eight levels, four for multiplication and four for division. Each player will proceed to the next "level" after passing the first "level", and they have to finish all tasks to reach the palace. The 'upgrades' received by players in the P-JMat application are shown in Figure 3.

**Figure 3**

*The transition experienced by the users of the P-JMat application*


The teaching materials in the P-JMat application focus on Basic Mathematical Operations, namely the sub-topics of multiplication and division. Each item included in the P-JMat is based on the primary school mathematics syllabus (DSKP) and verified by experts. After the expert discussion and evaluation, each learning topic was divided into four sub-skills to gradually ensure learning takes place in the P-JMat application, from easy to difficult. The progression of the difficulty level follows pupils' knowledge development based on their mastery of topics. Therefore, each sub-learning skill is set at the first level in the P-JMat application. Each level contains ten practise questions for pupils to complete. The division of sub-skills under multiplication and division is shown in Table 5.

**Table 5**

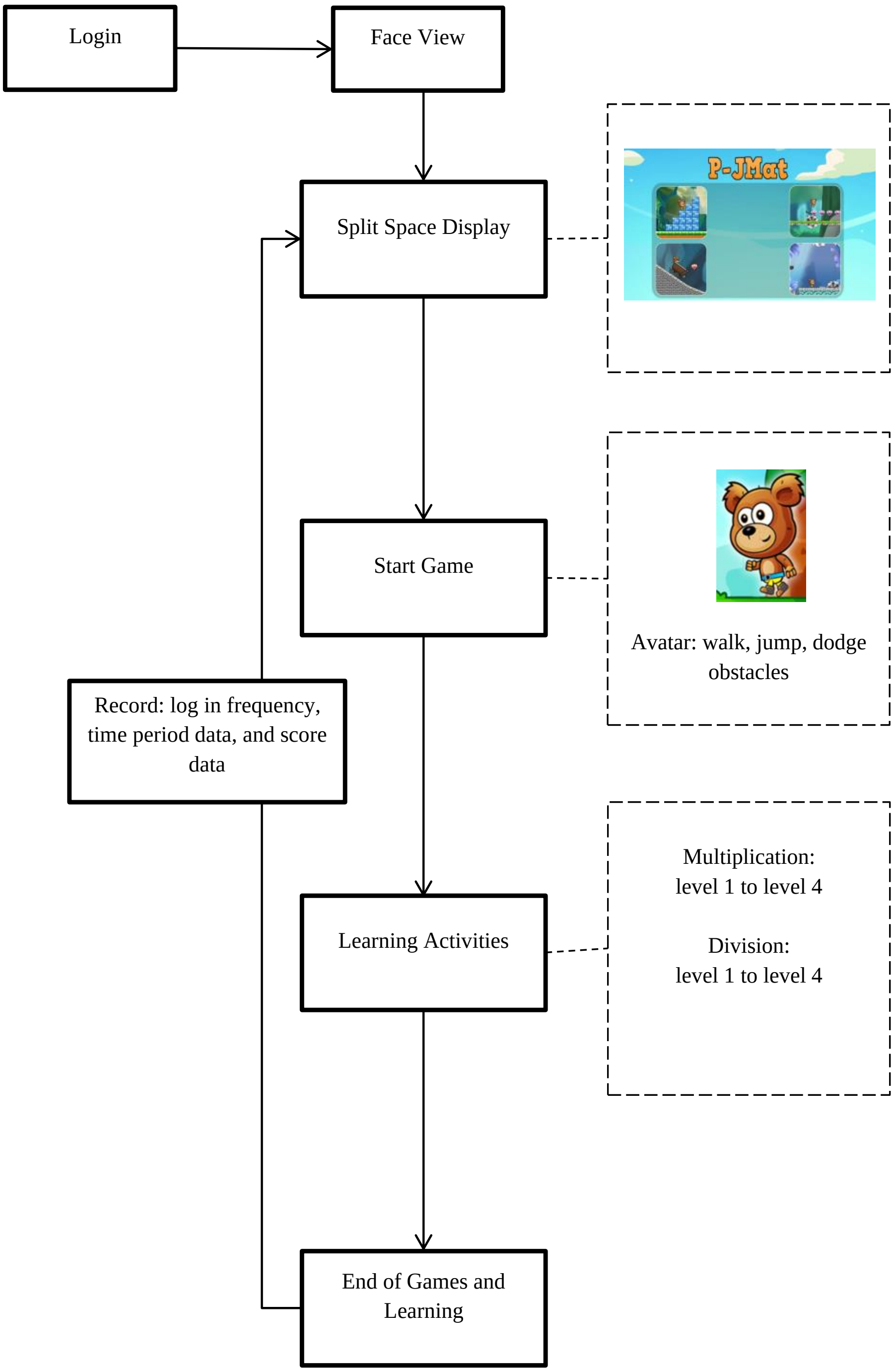
*The division of learning sub-skills of multiplication and division*

| Sub Topic | Skills Development |
|---|---|
| Multiplication | Level 1: Basic Multiplication |
| | Level 2: Multiply 2/ 3-digit numbers with 1-digit numbers without regrouping |
| | Level 3: Multiply 2/ 3-digit numbers with 1-digit numbers and regroup |
| | Level 4: multiply 4-digit numbers with 1-digit numbers with and without regrouping |
| | Level 1: Basic Division |
| Division | Level 2: Divide 2/ 3-digit numbers with 1-digit numbers without regrouping |
| | Level 3: Divide 2/3 3-digit numbers with the 1-digit number by regrouping |
| | Level 4: Divide 4-digit numbers with 1-digit numbers with and without regrouping |

The P-JMat application is also equipped with an instant feedback function on pupil learning actions. The immediate feedback provided by the P-JMat application can motivate pupils and encourage pupils to strive to the next level. This immediate response setting allows pupils to determine mistakes made. The setting of this instant feedback function is an important function that distinguishes between game-based learning and gamification. Feedback is an important factor in learning and has a huge impact on GBL (Yang & Lu, 2021). Therefore, the feedback given in the P-JMat application is divided into two: feedback for correct answers and feedback for incorrect answers. Feedback for the correct answers comprises encouragements such as “good job,” while feedback for the wrong answers will trigger responses about learning information. A summary of the gameplay and the learning process in the P-JMat application is shown in Figure 4.

**Figure 4**

*Summary of the learning process and games in the P-JMat application*



### 3.4 The Evaluation Stage

The evaluation phase comprises formative and summative evaluation. The formative evaluation includes reviewing technical features, content and the software. The content review includes reviewing the suitability of set objectives, the structure and quantity of lesson content, the validity of facts and concepts applied, the feasibility of the approach, and the alignment between the application with learning theories and strategies. In addition, a review of the technical aspects was done to ensure that the P-JMat application built can be used properly and does not give problems to users. The technical aspects were tested based on the basic system requirements, user interface design, text display, graphics, sound, and user guide. The last stage of the review ensures that the P-JMat application is interesting, and has interactive features as well as to identify its strengths and weaknesses.

A summative evaluation was carried out to evaluate the overall result of the P-JMat application. This ensures that the application meets the objectives and is aligned with the curriculum specifications. Ten evaluators were involved in the evaluation process. They comprise two officers from the Education Technology Division, three Primary school mathematics master trainers, two SISC+ officers for Primary school Mathematics, a Mathematics and STEM lecturer from the Institute of Teacher Education Malaysia (IPGM), and two national icons for innovation and technology. Moreover, the summative assessment was conducted with ten pupils using Post Study Usability and User Satisfaction Test (PSSUQ) questionnaire (Lewis, 2018). This questionnaire evaluated the P-JMat applications from various dimensions such as design, functionality, ease of use, learning ability, satisfaction, future use and error, and reliability.

## 4. THE GAME EVALUATION RESULTS

The usability of the P-JMat application was also evaluated formatively and summatively. A formative evaluation involved the pupils as users and was carried out to ensure that the design was well executed. Furthermore, a summative evaluation was carried out with the teachers and experts to collect data to evaluate the product's usability. The summative evaluation results are shown in Table 6.

**Table 6**

*The results of the summative evaluation*

| Construct | Evaluation Results | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | Overall Mean |
| System Uses | 1.66 | 1.00 | 2.30 | 1.33 | 1.00 | 1.16 | 1.25 | 1.67 | 1.33 | 1.83 | 1.28 |
| Information Quality | 2.00 | 1.33 | 1.16 | 1.66 | 1.50 | 1.16 | 1.00 | 2.33 | 1.50 | 1.66 | 1.53 |
| Interface Quality | 1.75 | 1.25 | 2.75 | 1.75 | 1.00 | 1.00 | 1.50 | 1.33 | 1.50 | 1.33 | 1.51 |
| Overall | 1.81 | 1.18 | 2.00 | 1.56 | 1.18 | 1.12 | 1.25 | 1.88 | 1.55 | 1.69 | 1.52 |

Notes: A = Appraiser

The summative evaluation results are shown in Table 7.

**Table 7**

*The results of pupils' summative evaluation*

| Construct | Evaluation Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | Overall Mean |
| System Uses | 1.00 | 1.33 | 1.50 | 1.50 | 1.00 | 1.00 | 1.33 | 1.33 | 1.00 | 1.00 | 1.20 |
| Information Quality | 1.33 | 1.33 | 1.33 | 1.00 | 1.00 | 1.00 | 1.16 | 1.33 | 1.00 | 1.00 | 1.15 |
| Interface Quality | 1.00 | 1.33 | 1.33 | 1.33 | 1.00 | 1.00 | 1.00 | 1.33 | 1.00 | 1.00 | 1.13 |
| Overall | 1.12 | 1.31 | 1.37 | 1.25 | 1.00 | 1.00 | 1.25 | 1.31 | 1.00 | 1.00 | 1.16 |

Noted: S = Pupil

Overall, the summative evaluation results give an initial impression that the P-JMat application is feasible in the primary classroom. The findings from the summative evaluation proved that the P-JMat application developed has met the objectives and specifications. The information obtained from the summative evaluation also showed the strength and applicability of the P-JMat application in increasing pupil motivation towards learning Mathematics, optimizing learning of Mathematics and improving pupils' Mathematics achievement Basic Mathematical Operations. The findings from this summative evaluation showed that pupils can use the P-JMat application for learning Mathematics. Furthermore, the quasi-test and post-test experimental study design with a non-equivalent control group used in this study has shown the effect of P-JMat application on pupils' motivation to learn Mathematics, self-efficacy in learning Mathematics, and achievement in Mathematics.

## 5. THE GAME MECHANICS

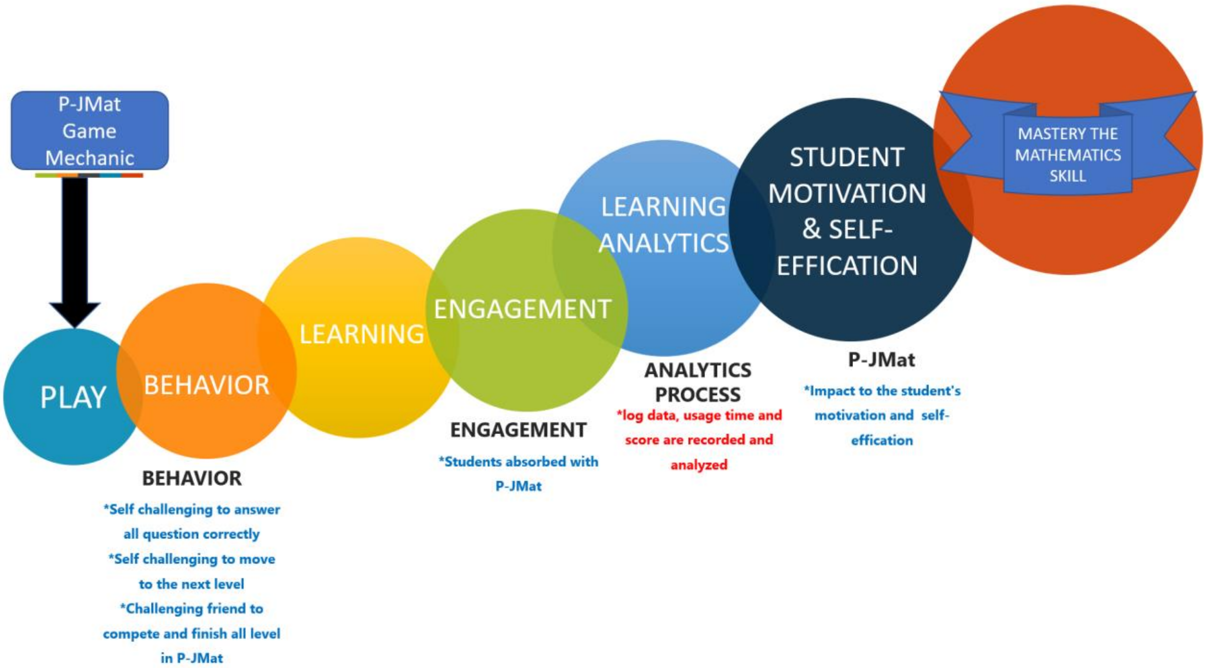
Users of the P-JMat app go through the face view, split space view, and game start to display as they play the game. The face view is the first image that the user sees when entering the P-JMat application. After pressing the "play" function button, the user will be taken to the split space view. The split space display shows the level pupils need to go through in the P-JMat application. There are four levels in all. Users can only go to the next level after passing the first level successfully by progressing and solving division questions until they reach the palace.

The behaviours formed while using the P-JMat will result in the potential of P-JMat in encouraging pupils to challenge themselves to answer all questions correctly, upgrade the level of difficulties, challenge peers to compete, and complete all levels in P- JMat. Thus, pupils will learn and master the topic of multiplication and division gradually through the P-JMat application. Consistent use of the P-JMat application will stimulate pupils' interest and provide a fun and enjoyable learning experience. Moreover, pupils will master all the skills in the P-JMat application, and their motivation and self-efficacy will be increased. As a result, using the P-JMat application will help pupils master the skills in the division well and thus improve pupils Mathematics achievement.

Pupils' data while using this application will be recorded and analyzed. LA is used in P-JMat to collect three data types to improve pupils' achievement. Data usage period data, visitor status data, and score data in the P-JMat application allow teachers to use LA to collect, measure, analyze, and report pupils' progress. The selection of various data types in the LA process helps teachers better understand the app's relevance to learning (Crescenzi-Lanna, 2020). Data analysis through LA could also help teachers understand the progression learning process and subsequently optimize Mathematics learning. A summary of the game mechanics in the P-JMat application is shown in Figure 5.

**Figure 5**

*Summary of game mechanic for P-JMat application*




## 6. CONCLUSION AND RECOMMENDATION

The design of the instructional GBL app with LA must be done carefully. Any instructional design model used should support the development of learning materials to achieve learning objectives. The P-JMat application development implies that it guides teachers in applying learning theories for classroom use. The effective application of theories allows the learning materials produced to be based on the foundations and principles of learning. This study has successfully designed and developed GBL and LA to present gamified content. The learning material offers a highly satisfying experience to pupils and teachers involved. A GBL-based application like P-Jmart could help create a meaningful learning environment and encourages pupils to explore knowledge via a fun approach. The application's features are designed to attract pupils' interest in learning mathematics and help improve their performance and confidence, foster creativity and positive motivation, and increase pupils' interest in Mathematics.

P-JMat's strength goes beyond GBL, and it is also equipped with analytical learning potential (LA) that had been poorly applied in previous learning materials. The LA application in P-JMat allows data from this application to be recorded and analyzed. This feature offers a new and innovative way of learning to meet the demand of industrial revolution 4.0 and 21st-century learning. The findings of this study can increase teachers' understanding of learning progression and enrich the Mathematics learning process. Moreover, LA helps teachers predict pupils' achievement, identify potential dropouts, and implement interventions to help pupils.

The P-JMat presents a carefully designed instructional GBL app integrated with LA. It guides teachers to apply learning theories optimally and ensure that the learning materials are grounded on foundations and principles of learning. As the GBL elements will stimulate pupils' motivation to learn and build positive pupil self-efficacy, the contents must correspond to the intended learning outcomes of the subject. In this sense, game designers and developers must possess a certain understanding of the content. Prototyping is critical to ensure that instructional components and game elements are intertwined cohesively. It is recommended to add more levels to the P-JMat application to accommodate the learning process for a longer period. This will increase the frequency of pupil visits in the app, increase the duration of app usage and improve score data from app usage. The rich data obtained from the P-JMat application ensure the LA process has been implemented effectively. Lastly, further study could quantify the application's learnings, skills, and achievements.

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## REFERENCES

Bertram L. (2020). Digital Learning Games for Mathematics and Computer Science Education: The Need for Preregistered RCTs, Standardized Methodology, and Advanced Technology. *Front. Psychol.* 11:2127. doi: 10.3389/fpsyg.2020.02127

Brezovszky, B., McMullen, J., Veermans, K., Hannula-Sormunen, M. M., Rodríguez-Aflecht, G., Pongsakdi, N., Laakkonen, E., et al. (2019). Effects of a mathematics game-based learning environment on primary school students' adaptive number knowledge. *Computers and Education* 128: 63–74. doi:10.1016/j.compedu.2018.09.011

Brown G.T.L. (2020). Schooling Beyond COVID-19: An Unevenly Distributed Future. *Front. Educ.* 5:82. doi: 10.3389/feduc.2020.00082

Cheung, S. Y. & Ng, K. Y. (2021). Application of the Educational Game to Enhance Student Learning. *Frontiers in Education* 6(March): 1–10. doi:10.3389/feduc.2021.623793

Crescenzi-Lanna, L. (2020). Multimodal Learning Analytics research with young children: A systematic review. *British Journal of Educational Technology* 51(5): 1485–1504. doi:10.1111/bjet.12959.

Creswell J. W., Creswell J.D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Method Approaches (Fifth edition)*. London: SAGE Publication, Inc.

Dani, A. (2016). Student's Patterns of Interaction with a Mathematics Intelligent Tutor: Learning Analytics Application. *International Journal on Integrating Technology in Education*. doi:10.5121/ijite.2016.5201

Dele-Ajayi, O., Strachan, R., Pickard, A. J. & Sanderson, J. J. (2019). Games for Teaching Mathematics in Nigeria: What Happens to Pupils' Engagement and Traditional Classroom Dynamics? *IEEE Access* 7: 53248–53261. doi:10.1109/ACCESS.2019.2912359

Ebner, M., & Pronegg, M. (2015). Use of Learning-Analytics-Applications in Mathematic with Elementary Learners. *International Journal of Academic Research in Education* 1(2): 26-39.

Eseryel D, Law V, Ifenthaler D, Ge X, Miller R . (2014). An investigation of the in- terrelationships between motivation, engagement, and complex problem solving in game-based learning. *Educational Technology & Society* 17(1):42–53.

Farber, M. (2015). *Gamify your classroom: A field guide to game-based learning*. New York: Peter Lang

Fuster-Guilló A, Pertegal-Felices ML, Jimeno-Morenilla A, Azorín-López J, Rico-Soliveres ML and Restrepo-Calle F. (2019). Evaluating Impact on Motivation and Academic Performance of a Game-Based Learning Experience Using Kahoot. *Front. Psychol.* 10:2843. doi: 10.3389/fpsyg.2019.02843

Huang, S. & Fang, N. (2013). Computers & Education Predicting student academic performance in an engineering dynamics course : A comparison of four types of predictive mathematical models. *Computers & Education* 61: 133–145. doi:10.1016/j.compedu.2012.08.015.

Hue, J. P., Kang, I. A. & Shin, S. S. (2015). A case study of applying learning analytics in general mathematics class. *Indian Journal of Science and Technology*. doi:10.17485/ijst/2015/v8i21/78382

Hussain, M., Zhu, W., Zhang, W., Abidi, S. M. R. & Ali, S. (2019). Using machine learning to predict student difficulties from learning session data. *Artificial Intelligence Review* 52(1): 381–407. doi:10.1007/s10462-018-9620-8

Hussain, S. Y. S., Tan, W. H., & Idris, M. Z. (2014). Digital game-based learning for remedial mathematics students: A new teaching and learning approach in Malaysia. *International Journal of Multimedia Ubiquitous Engineering*, 9(11), 325-338.

Hsu, M. E., & Cheng, M. T. (2021). Immersion experiences and behavioural patterns in game-based learning. *British Journal of Educational Technology*.

Ingram, N., Williamson-Leadley, S. & Pratt, K. (2016). Showing and telling: using tablet technology to engage students in mathematics. *Mathematics Education Research Journal*. doi:10.1007/s13394-015-0162-y

Kim, D. R., Hue, J. P. & Shin, S. S. (2016). Application of learning analytics in university mathematics education. *Indian Journal of Science and Technology* 9(46). doi:10.17485/ijst/2016/v9i46/107193

Lai, C.-L. & Hwang, G.-J. (2016). A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. *Computers & Education* 100: 126–140. doi:10.1016/j.compedu.2016.05.006

Lewis, J. R. (2018). Measuring perceived usability: The CSUQ, SUS, and UMUX. *International Journal of Human–Computer Interaction* 34(12): 1148-1156.

Lu, O. H. T., Huang, A. Y. Q., Huang, J. C. H., Lin, A. J. Q. & Yang, S. J. H. (2018). Applying Learning Analytics for the Early Prediction of Students ' Academic Performance in Blended Learning. *Educational Technology & Society* 17(1):42–53.

Marcial, D. E., dela Peña, L., Montemayor, J. & Dy, J. (2021). The Design of a Gamified Responsible Use of Social Media. *Frontiers in Education* 6(March). doi:10.3389/feduc.2021.635278

Merriam, S.B. & Tisdell, E.J. (2016). *Qualitative Research: A Guide to Design and Implementation (Fourth Edition)*. San Francisco

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS medicine*, 6(7), e1000097.

Nadolny, L., Valai, A., Cherrez, N. J., Elrick, D., Lovett, A. & Nowatzke, M. (2020). Examining the characteristics of game-based learning: A content analysis and design framework. *Computers and Education* 156(May): 103936. doi:10.1016/j.compedu.2020.103936

Niemelä, M., Kärkkäinen, T., Äyrämö, S., Ronimus, M., Richardson, U. & Lyytinen, H. (2020). Game learning analytics for understanding reading skills in transparent writing system. *British Journal of Educational Technology* 0(0): 1–15. doi:10.1111/bjet.12916

Okur, M. & Aygenc, E. (2018). Video games as teaching and learning tool for environmental and space design. E*urasia Journal of Mathematics, Science and Technology Education* 14(3): 977–985. doi:10.12973/ejmste/80932

Orgaz, G., Jung, J. J., & Camacho, D. (2016). Social big data: Recent achievements and new challenges. *Information Fusion* 28: 45-59.

Oyerinde, O. D. (2017). Predicting Students ' Academic Performances – A Learning Analytics Approach using Multiple Linear Regression 157(4): 37–44.

Piaget, J. (1980). *Experiments in Contradiction*. Chicago: The University of Chicago Press.

Román-González, M., Pérez-González, J. C., Moreno-León, J. & Robles, G. (2018). Can computational talent be detected? Predictive validity of the Computational Thinking Test. *International Journal of Child-Computer*

*Interaction*. doi:10.1016/j.ijcci.2018.06.004

Romero, C., & Ventura, S. (2010). Educational data mining: a review of the state of the art. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, 40(6), 601-618.

Siemens, G. and Baker, R. S. J. (2012). Learning Analytics and Educational Data Mining: Towards Communication and Collaboration. *LAK '12 Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*: 252- 254.

Steinmaurer, A., Pirker, J. & Christian, G. (2020). The Challenges of the Digital Transformation in Education 917: 614–625. doi:10.1007/978-3-030-11935-5

Sweller, J., Van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review* 10 (3)251-296.

Tshewang, R., Chandra, V. & Yeh, A. (2017). Students' and teachers' perceptions of classroom learning environment in Bhutanese eighth-grade mathematics classes. *Learning Environments Research* 20(2): 269–288. doi:10.1007/s10984-016-9225-6

Tokac, U., Novak, E. & Thompson, C. G. (2019). Effects of game-based learning on students' mathematics achievement: A meta-analysis. *Journal of Computer Assisted Learning* 35(3): 407–420. doi:10.1111/jcal.12347.

Van Merriënboer, J. J. G. & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review* 17. doi:10.1007/s10648-005-3951-0.

Vladimir L., U., Jeffrey P., B., Ashok, S., Timothy, K., Alexander, U., Jitendra, S. & Rama, R. (2019). Smart Learning Analytics: Conceptual Modeling and Agile Engineering. *International KES Conference on Smart Education and Smart E-Learning. Springer, Cham* 59: 291–301. doi:10.1007/978-3-319-39690-3.

Walter Dick, Lao Carey, J. O. C. (2015). *The Systematic Design of Instruction*. Pearson Education Vol. 8.

Wu, M. L., Richards, K. & Saw, G. K. (2014). Examining a Massive Multiplayer Online Role-Playing Game as a Digital Game-Based Learning Platform. *Computers in the Schools* 31(1–2): 65–83. doi:10.1080/07380569.2013.878975.

Yang, K. H., & Lu, B. C. (2021). Towards the successful game-based learning: Detection and feedback to misconceptions is the key. *Computers & Education* 160: 104033.

Ylinen S, Smolander A-R, Karhila R, Kakouros S, Lipsanen J, Huotilainen M and Kurimo M. (2021). The Effects of a Digital Articulatory Game on the Ability to Perceive Speech-Sound Contrasts in Another Language. *Front. Educ.* 6:612457. doi: 10.3389/feduc.2021.612457

Zou, D., Zhang, R. & Wang, F. L. (2021). Digital game-based learning of information literacy : Effects of gameplay modes on university students ' learning performance , motivation , self-efficacy and flow experiences 37(2): 152–170.