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Analyzing Learning Process on Educational Assessment and Its Theoretical Concepts Using Motion in Mind

ANUNPATTANA PUNYAWEE

Supervisor: **Professor Hiroyuki Iida**

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy of Information Science

Graduate School of Advanced Science and Technology
Japan Advanced Institute of Science and Technology
Japan

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Doctoral Dissertation

Analyzing Learning Process on Educational Assessment and Its Theoretical Concepts Using Motion in Mind

Punyawee Anunpattana

Supervisor: Hiroyuki Iida

Graduate School of Advanced Science and Technology

Japan Advanced Institute of Science and Technology

[Information Science]

March 2023

Supervised by

Prof. Dr. Hiroyuki Iida

Reviewed by

Prof. Dr. Kokolo Ikeda

Prof. Dr. Shinobu Hasegawa

Prof. Dr. Jin Yoshimura

Prof. Dr. Wilawan Inchamnan

Abstract

Learning is essential for cognitive development and the acquisition of abilities that express the essence of every human being. Several studies have shown that learning can be facilitated in various ways, including real-life tasks and the incorporation of gamified experiences. Gamification, the incorporation of game elements into non-game contexts, has shown the potential to enhance learning outcomes and increase engagement in educational settings. Several analyses have investigated different techniques to improve learning and maintain student engagement, including the use of challenge-based gamification, flow theory, the zone of proximal development, and prospect theory.

This dissertation presents a comprehensive study on the use of gamification techniques in educational assessments, specifically multiple-choice questions (MCQs). The research employs a mixed-method approach, combining qualitative and quantitative methods, and makes use of numerical computation to evaluate the effectiveness of incorporating these theoretical frameworks into educational assessments to allow for a more comprehensive understanding of the impact of gamification on the learning process. The findings suggest that gamification can be an effective way to enhance learning outcomes and increase engagement in educational contexts. By considering these theoretical frameworks, it is possible to design educational assessments that foster a sense of competence and enjoyment during the learning process, while also balancing competitiveness and enjoyment. This approach can be particularly promising for complementing standardized testing and classroom activities and for bridging the gap between game and non-game contexts.

The main objective of this dissertation is to precisely evaluate and determine the individual's perceived impact and learning process on the educational assessment evolution over time: 1) To capture the impact of the variation in challenge-based gamification over the educational assessment. The purpose was to investigate the optimal level of gamification in the activity and state the position of individual motion using both concepts of motion in mind and flow theory to bridge the gap between physics and psychology 2) To define the learning comfort based on theoretical approaches using the Kahoot (Quizzing) and MCQs (Testing) testbed. Integrating the scaffolding-based concept in the test characteristics and properties could be described by the motion in mind and zone of proximal development to bridge the gap between physics and learning theory. Also, Introducing the framing effect enables the applicability of prospect theory under decision-making activity 3) To develop the link between learning and play by proposing a new measurement of motion-in-mind perspective that indicates learning processes. Proposing the objectivity and subjectivity measures ensures the conjecture between learning comfort and playing comfort based on the objective point of view. The findings provide a basis for further application in the educational context. Particularly in a conceptual learning environment, a balance between uncertainty and ability is required to emphasize their significance in education. In addition, this dissertation makes a significant contribution to the understanding of how gamification can facilitate the learning process in educational contexts. The practical implications of this research may be useful for educators and researchers looking to enhance student engagement and learning outcomes through the incorporation of gamified techniques into educational assessments. By thoroughly the analysis process, this study increases the transparency and credibility of the findings, providing a strong foundation for future directions.

Overall, this dissertation presents a detailed and robust examination of the use of gamification in educational assessments, specifically MCQs. The proposed approach may be particularly promising for increasing the sense of competence and enjoyment during the learning process and for enhancing learning outcomes and engagement in educational settings. The findings and practical implications of this research offer valuable insights for educators and researchers looking to improve learning and engagement in educational contexts.

Keywords: *Challenge-based Gamification, Motion-in-Mind, Game Refinement Theory, Educational Assessment, Learning Process*

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CHAPTER 1

Introduction

1.1 Chapter Introduction

This dissertation represents the framework to contribute learning process in educational assessment by linking several theoretical concepts and computing them based on motion-in-mind measures. This chapter first outlines the background and the need to emphasize educational assessment, which provides the importance of educational assessment and its theoretical concepts related to engagement and the learning process in section 1.2. Then, we mention our problem statements, including the research questions, and the scope of this dissertation in section 1.3 and section 1.4, respectively. The dissertation objectives and significance are given in Section 1.5. Finally, the structure of this dissertation is explained in Section 1.6.

1.2 Background

Learning is an ongoing process of acquiring knowledge and abilities that never ends since life never stops teaching us. In one of his quotes, Albert Einstein said, "Once you stop learning, you start dying". Learning new things is essential for enabling cognitive development, especially in every human being, since it holds the fact that every individual has the potential to improve their competencies. A basic ground of learning begins with adopting the recall process, repetition, internalization, and externalization of information [1]. Individuals can learn from several mediums and informative platforms, then apply them to daily life. Mainly, there is an endless collection of new knowledge, skills, and abilities to investigate and acquire amid the advancement of technology and the progress of society.

Recently, two most common phrases for integrating learning and entertainment have emerged: "learn through play" and "edutainment.". Through play, a learner can develop, alter, and understand. All these basic skills are developed as they explore, construct, imitate, discuss, plan, manipulate, problem-solve, dramatize, create and experiment [2]. Play is a most promising practice since its purpose permits intrinsic motivation to acquire skill without knowing it and in the most natural way. The role of play in human culture's development can be discovered in the play theory of Huizinga [3]. Its potential is generally highlighted in various ways. Scholars from several disciplines agreed that play has no single place and can vary depending on the context. Numerous research has revealed that play is a full learning mode essential to an individual's learning. Learning can be supported in diverse ways in which individuals learn, such as through real-life tasks, storytelling, and the inclusion of gamified experience [4]. The definition of play and learning has explained the vital factor based on the assumption that engagement and motivation are crucial for the learning environment.

In the educational classroom, the critical goal is to contribute to learning in a meaningful way to acquire new information. A century of research has been devoted to studying several approaches to enhance learning and maintain learner engagement. The current meta-analysis discovers that testing has a reliable advantage over alternative procedures in facilitating classroom learning of factual knowledge, concept comprehension, and knowledge application. Several attempts are to identify a perception between learning and development in educational assessment.

Testing can enhance learning motivation in several ways [1]. It is an important motivator driving students to commit more effort to prepare for a subsequent task [5, 6]. It thus motivates them to expend more effort to narrow the perceived gap in their abilities. The ubiquity of multiple-choice questions in current educational assessments stems from its many advantages relative to other assessment formats. There are dozens of test formats employed in classroom quizzes [7], such as fill-in-the-blank, cued recall, free recall, short answer, matching, multiple choice, and essays. Exploring which testing formats are most efficient for enhancing classroom learning is crucial.

Its effectiveness and properties can be identified from descriptive statistics; in some ways, we can also analyze testing formats by using computer science and other related methods to broaden enhancements, such as the number of options, scoring methods, how accurate quality assessment, and the progress the individual experience to reach a sound point. Numerous research studies over the last century have proved that testing is an effective intervention for improving the long-term retention of learned knowledge and facilitating mastery of new information. The testing effect is associated with restudying and many other learning processes.

This premise contributes to the possibility of consolidating the effective way to improve learning potential and facilitate a long-term environment. The educational intervention, by referring to both entertainment and education perspectives, exposes the merits and shortcomings in the game design. It fosters curiosity and assesses the informative learning process [8, 9, 10]. At the same time, the researchers emphasize how to incorporate gamified elements in educational schemes.

Most educators have stumbled across these two terms: gamification and game-based learning (GBL). In comparison, gamification is the application of game mechanics in a non-game context to promote and reinforce motivation in order to improve existing modules, which drives learning outcomes. Game-based learning uses game elements to achieve a specific learning outcome, which ensures an enjoyable experience. According to the gamification literature, gamification has been used primarily in education to understand the relationships and provide empirical support in this field, which has been applied in several studies [11, 12, 13, 14, 10]. Gamified education platforms have been employed to study the effect of gamified learning and engagement. They can be easily shaped and configured in various subjects and introduce game elements into classrooms without effort. Using a gamified platform as a formative assessment platform encourages students to engage in the learning environment [9, 15]; it enables them to develop their performance to accomplish the tasks or activities. Because gamification does not directly improve learning outcomes, a sense of engagement emerges, which leads to behavior change [16]. Therefore, learning-related behavior is introduced as an analogical bridge to contribute to the learning process [17].

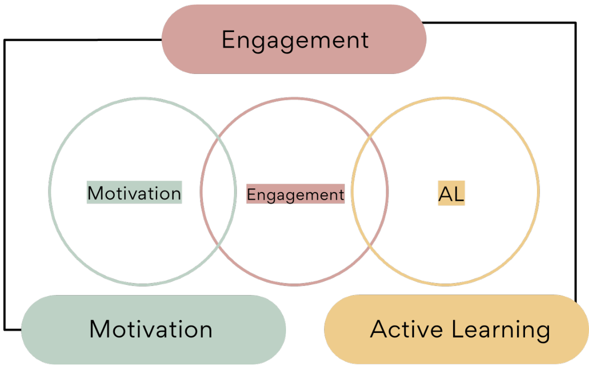


FIGURE 1.1. Diagram of student engagement model, adapted from [18]

For several decades, the topic of engagement has been the focus of many studies. According to Barkley [18], student engagement is the outcome of motivation and active learning. As a result of the intersection of these components, engagement takes place (see Figure 1.1) [19]. The learning process can be tailored by discipline in a way that promotes engagement by delivering a diverse range of content with a reasonable range. To maximize learning outcomes, its implementation must demonstrate an improvement in motivation in a short-term outcome and learning engagement in a long-term consequence. These outcomes allow for individual explorations and adaptability. The essential issue for an individual's learning is to create a perceived supportive environment in which individuals actively engage in relevant tasks that entail uncertainties and challenges.

Interestingly, learning and engagement are essential elements suitable for robust, well-balanced, long-term consequences in educational aspects. Motivation is a crucial component to achieving intended learning outcomes. One aspect of motivation is engagement: if an individual is engaged in learning, then the individual is motivated to learn. Moving into the learning zone might feel tense at first. However, it does allow individuals to be curious and engaged in learning. Individuals might feel a little pressure at the prospect of this new challenge, but this pressure can have a positive impact, pushing you to succeed without making you struggle or panic. Ideally, as individuals spend more time beyond their ability, their mastery of new skills will improve. Some of these new skills will then pass into your comfort zone, which signifies that the learning process was achieved.

The mechanism of challenges in education has continuously been addressed by integrating gamification, but a gap still needs empirical evidence in many theoretical aspects which support user engagement. In order to acquire a new skill, the challenge plays a prominent role in producing different motivational outcomes that depend on the context of use. The concept of the challenge is initially developed in the playing context, which might be translated into the educational context, i.e., education is influenced by such a perspective of learning under uncertainty and overcoming more challenging tasks corresponding to the reasonable ability level and a basis of high-stakes decisions. Several educational systems and e-learning platforms support the benefits of increasing student motivation or generating learning-related outcomes in the early stages of education [20]; some extant research examined gamification targeted to increasing the amount of effort applied in activities related to these goals [21, 22]. Creating a challenge between these two contexts of play and learning might be best for engagement- or learning-related outcomes. This would be creative to integrate challenge-based elements into educational activities to improve the efficiency of acquiring knowledge and unlocking the hidden skills in such challenging tasks. It is also helpful to consider another aspect to determine how to support the learning activity. With these mentions, this would be an interesting point to investigate what kind of activity is optimal for yielding the learning process.

The simple question raises several profound problems. Moving beyond the comfort zone is one of the main points to yield the learning process. This idea originated from psychologist Lev Vygotsky [23], who demonstrates how to learn successfully and elaborates that the relationship between learning and development is understood as the learning process leading to results (solving a problem or task) [24]. The learning process usually occurs in the arousal area, where individuals perceive an intense, greater challenge than their ability level. In order to learn successfully, the desired activity must be challenged. The balance is thus a dominant factor in keeping an individual's state of mind, along with driving a reasonable effort. A task or an activity should be challenged so that the balance needs is just right. One of the numerous significant works was elucidated by the flow theory [25], where the understanding of the challenge in games that drives a sense of flow and engagement was met with the improvement of the individual's ability level. However, every individual has differences in strength and expertise. The individual differences in doing tasks rely on the individual's behavior and ability level. It can be seen that the concept of integrating education and entertainment has been increasingly popular in recent decades.

Many factors affect engagement and the learning process in positive and negative fashions. It is crucial that educators comprehensively understand them and tailor formative and summative assessments accordingly. Therefore, analyzing the learning process in the educational assessment by linking theoretical concepts should be the bottom line in an effective educational environment. This dissertation focuses on the theoretical concepts from objective and subjective viewpoints and the evolution of educational assessment. The contribution of this dissertation has the potential to reveal significant improvement in learning, motivation, engagement, enjoyment, and impact of the gamified approach. Using motion in mind [26], new insights can be generalized to determine a dynamic learning process in non-game contexts. The following section discusses the problem statement and crucial points to be considered that can be achieved within the scope of the educational and playing contexts.

1.3 Problem Statements

According to the previous section's overview, individuals have different preferences and educational levels in perceiving learning and engagement in a given task. It is essential to highlight the motivators that produce more significant learning improvement and investigate their underlying mechanism. Previous theoretical investigations have been derived from limited applicability to the educational classroom [11, 27, 8]. Many studies have primarily looked at the objective aspects of test-enhanced learning without examining its subjective aspects. By exploring the cognitive and motivational foundations of test-enhanced learning and how it applies in educational contexts, we may be able to improve its use in education.

As we mentioned, we found a research gap between motivation and engagement regarding the validation of challenge-based gamification impacts on learner motivation and engagement. There are still opportunities to broaden its cognition of gamification since it is scarce to justify how gamification works intrinsically. By using the mathematical expression, it might be helpful to translate the result into both objective and subjective viewpoints. This gap must be addressed to justify reasonable methods in practical way, which was the core focus of this study. The first problem statement is thus stated here below.

Problem Statement 1. How to improve an engagement and learning-related outcomes by using challenge-based gamification in the educational context.

To date, evaluation and assessment in education are critical markers of educators' performance and achievements. The scholar stated that a test as a measurement instrument aimed to numerically characterize the degree or amount of learning under uniform and standardized conditions [28]. It has been difficult to identify the optimal formative assessments for a legitimate goal because a test that is advantageous in one setting may be completely inappropriate in another; in other words, there is no one-size-fits-all test structure. Most of this study has been on enhancing the reliability and validity of multiple-choice examinations by removing non-functional distractors, reducing the guessing effect, and eliminating potential sources of confusion. Researchers developed many best practices by incorporating the findings of these studies in order to provide practical recommendations for instructors [29, 30]. As a result, questions have been raised on several points in order to establish a more precise evaluation and accuracy in individual performance. The second problem statement is stated here below.

Problem Statement 2. How to determine the most effective assessment methods for promoting learning process.

Analyzing how theoretical concepts to support engagement and the learning process in educational assessment is the research problem addressed. Addressing these statements will deliver insight into adjusting game elements and evaluation strategies. The specific research questions in this research are as follows:

- **Research Question 1** According to problem statement 1, this question focuses on particular approaches that extend the range of educational assessment. There needs to be existing knowledge on how we might design and develop the assessment to support and facilitate individual engagement in the educational assessment. The relationship between the variation of the educational assessment and individual experience is investigated in the education context using the motion in mind theory.
- **Research Question 2** The harmony between learning and engagement is generalized using the output from research question 1. This question focuses on the extent to which the educational assessment fosters the learning process. The research allows the motion in mind to measure the extent to which specific individual experiences facilitate learning comfort.
- **Research Question 3** This question focuses on the characteristics of the learning process that may occur during an educational assessment. How the learning process might be measured within an educational context needs to be clarified. Addressing this aim requires the motion in mind concept related to objectivity and subjectivity within an education context. Adopting its characteristics allows for measuring the learning comfort, fairness perspective, and competitiveness within an education context. Throughout the dissertation, we investigate the interpretation of learning comfort, learning process, and learning engagement within the educational assessment paradigm using motion in mind theory.

For each chapter, we aim to use various methodologies which will be approached to answer the research questions.

1.4 Scope of this Dissertation

As we have stated, this dissertation aims to analyze the learning process in the proposed educational assessment and then interpret the learning process by linking proposed theoretical concepts to understand the nature and meaning of educational impact and characteristics. For clarification, the scope of this dissertation is addressed from the two perspectives below.

- **Engagement** Engagement is an essentially emotional component directly linked to motivation and flow and is influenced partly by challenge, mastery, pressure, and escapism [31]. Its characteristics in educational activity and assessment include many aspects. This dissertation primarily focuses on learning engagement. Learning engagement is the ability to motivationally and behaviorally engage in an effective learning process. People acknowledge responsibility for their decisions, using feedback, evaluating personal behavior, and analyzing appropriate responses to engage in learning activities and make efforts for growth on their initiative. Motivation is associated with the potential energy when considering learning engagement based on the motion in mind perspective, which addresses the weight of information progress through expectation and engagement to learn [32]. Different approaches can be used to improve learning or performance over time and translated into different viewpoints. In this regard, this dissertation incorporates engagement based on the indicator of the mass in mind. Based on the flow theory, mass in mind and solving rate are equivalent, and gamified elements will improve mass in mind over time to reach engagement at the competitive aspect. For this reason, engagement can be indicated as the point where subjective reinforcement dominates over objective reinforcement from a potential energy viewpoint.
- **Learning** Learning improvement can be evaluated in several aspects. This dissertation primarily focuses on the learning process. The learning process is when people learn new knowledge and abilities, eventually influencing their attitudes, decisions, and behavior. The activity can carry out learning improvements so that individuals can achieve educational objectives. Applying knowledge and combining cognitive abilities characterize learning improvement, in which the learning process can be objectively and subjectively grown over time. Consisting of several approaches in this dissertation, the learning process that achieved a change in reward frequency must address learning improvements. The learning process that can be acquired, optimized, and supported will improve mass in mind over time until learning comfort is reached. Curiosity can be an indicator of the learning process and be achieved at a point where objective reinforcement dominates over subjective reinforcement

from a potential energy viewpoint. In this regard, this dissertation incorporates a reinforcement schedule as the variable ratio for indicating learning improvements.

1.5 Dissertation Objectives and Significance

The main objective of this dissertation is to evaluate the impact of the educational assessment evolution on individual learning processes over time. The use of the motion-in-mind perspective provides valuable insights into bridging the gap between game and non-game contexts. To optimize assessment and improve motivation and learning capabilities, this dissertation proposes a game progress model and motion-in-mind measures. The proposed experiment considers engagement, curiosity, and learning-related outcomes under internal uncertainty to achieve high motivation levels and successful learning. The obtained data will address current research gaps and provide a practical approach to support standardized tests and classroom activities.

- To capture the impact of the variation in challenge-based gamification over the educational assessment. This study aimed to determine the optimal level of gamification and position of individual motion, bridging physics and psychology using motion-in-mind and flow theory. The study proposes a mechanism of challenge-based gamification in education, improving engagement and learning potential by capturing a learner's standpoint.
- To define the learning comfort based on theoretical approaches using the MCQs testbed. Integrating the scaffolding-based concept in the test characteristics and properties could be described by the motion in mind and zone of proximal development to bridge the gap between physics and learning theory. Also, introducing the framing effect enables the applicability of prospect theory under decision-making activity. These premises demonstrate the common perception and highlight the indicative factors for enabling the learning process, which can be found in educational scenarios, such as development and risk-seeking.

- To develop the link between learning and play by proposing a new measurement of motion-in-mind perspective that indicates learning processes. Proposing the objectivity and subjectivity measures ensures the conjecture between learning comfort and playing comfort based on the objective point of view. To ensure the learning process, theoretical concepts are included to develop the interpretations and justify the findings. The findings provide a basis for further application in the educational context. Particularly in a conceptual learning environment, a balance between uncertainty and ability is required to emphasize their significance in education.

The significance of this dissertation is that it provides a comprehensive exploration of this study on the application of gamified learning in the education context. A link between playing and learning consists of challenges and abilities that can be addressed by gamification and learning theory using motion-in-mind measures. The proposed measurement will identify the response and influence of learning-related behavior. Then, the link between the underlying gamification relative to learning and playing will be established. In this regard, the stakeholders and educators will have a new approach to managing this framework by incorporating and integrating its applicability and practical implications. The overview research will drive new paradigms and interpretations, which will be helpful in the future direction.

1.6 Structure of Dissertation

There are four further chapters in this dissertation, organized as follows.

- **Chapter 2: Literature Review** This chapter overviews the existing educational assessment literature with identified research gaps. The first section covers the theoretical background of learning in an educational context, including state-of-the-art research in this field. Secondly, it provides an overview of an educational assessment, including its definition and characteristics. The third section covers the theoretical concept and its relationship described in this dissertation in various aspects of the learning process, including motivation, engagement, and learning outcomes. The last section introduces uncertainty, objectivity, and subjectivity measurement with game refinement theory and motion in mind. They are essential grounds for the educational aspects in which linking and interpretation are addressed based on these theories. At the end of the chapter, a conclusion that leads to the justification of the research carried out in the dissertation will be addressed.

- **Chapter 3:** This chapter reveals the first example of using challenge-based gamification (CBG) to capture the impact based on the motion in mind theory. The report in this chapter covers the research results that potentially impact engagement and learning using gamified quizzing, Kahoot!, as a testbed. The details outline results obtained from integrating challenge-based gamification. The approach was applied to logical puzzle quizzes where different game elements were adjusted and computed using the motion-in-mind concept. Time pressure, difficulty, and adaptations are included in the main experiments, which show how motion in mind theory can be used for finding a comfortable and gamified setting in the educational activity. The structural experiment, with a mixed methods design, was designed around the notion of time pressure and the difficulty of gamified quizzing experience. This model was constructed to validate and expand the quantitative findings (motion in mind model) by including qualitative explorations (thematic analysis). The results revealed the potential synthesis of motion in mind and flow theory, and its relationships to engagement and learning were identified as a new conceptual scheme.
- **Chapter 4:** This chapter presents a popular paradigm of decision-making activity or problem-solving. Multiple-choice questions (MCQs) are introduced to generalize the concept of learning comfort in the education context. This study aims to link theoretical concepts, including challenge-based gamification, flow theory, zone of proximal development, and prospect theory, and generate insight into educational assessment using motion-in-mind measures. Classical test theory (CTT) was used to determine reliability and validity. MCQs were experimented with: the number of options, settings, and scoring methods. The experimental data was gathered from human and AI simulations and measured using motion in mind. This study revisits the notion of learning comfort based on mass value of the motion-in-mind perspective, especially this study alings the reinforcement and curiosity interpretation to serve

the education context. At the end of this chapter, the results addressed the general discussion, which is helpful in linking analogical interpretation in the education context based on physics-in-mind values. The findings can be an extension study for analyzing the balance between competitiveness and entertainment while seeking the learning process in the educational context. The variations of MCQs regarding measures using motion in mind with perspectives of other theories were proposed to mark the learning process.

- **Chapter 5:** This chapter covers and suggests the conclusion of this thesis. It includes the significance of the findings and . Limitation of the dissertation will be addressed. According to the findings in the previous chapter, the findings will be addressed the possible best answer to the research questions and explain the contribution of this study. Consolidation of the study and general implications are covered and recommendations for future works will be included in the last section of this chapter.

CHAPTER 2

Literature Review

2.1 Chapter Introduction

This chapter presents a review of current research in education, focusing on engagement, the learning process, and educational assessment. It discusses how variations in educational assessment impact engagement and the learning process and introduce theoretical concepts that support them. The chapter provides an overview of educational assessment and its state-of-the-art research, as well as covers the relationship between motivation, engagement, learning outcomes, and theoretical concepts. Finally, it addresses uncertainty, objectivity, and subjectivity measurement using game refinement theory and motion in mind. They are essential grounds for the educational aspects in which linking and interpretation are addressed based on these theories. At the end of the chapter, the conclusion justifies the research carried out in the dissertation.

2.2 Learning in Education

This section reviews the literature focusing on learning in an educational context which encourages individual engagement and learning-related outcomes. Research on learning in education has resulted in several aspects, interpretations, and models.

Learning is a crucial important notion in human behavior. The improvement of behavior resulting from experience is referred to as learning. The phenomena of learning are essential for human growth. Various psychologists have interpreted learning from various perspectives. Learning is a broad term that has been defined in several ways. Some define learning as a process, while others define it as a shift in ability, and yet others define it as the acquisition and retention of knowledge. As a result, the definitions of learning in education, the following facts come to light. Learning refers to acquiring new knowledge, and new responses are the process of learning. People involve in understanding behavior described as the process of progressive behavior adoption [33]. Towards the entire situation is learning, motivation has a significant role in the learning process.

Individuals must engage in learning activities in order to learn. The notion of engagement divides engaged learning into two categories: 1. activities that entail active cognitive processes and 2. individuals who are intrinsically driven to learn because of an indicative learning environment. From this perspective, engagement is a crucial component of motivation; the focus is on designing tasks to increase motivation. There is also a difference in generalization: engagement refers to a task. In this dissertation, the term engagement is designated as the ability to engage in an effective learning process both motivationally and behaviorally.

Numerous investigation has been done in the engagement term, considering the education context [8]. There is a distinction between extrinsically and intrinsically motivated engagement, which might offer differing results in effectively achieving the objective goal, especially when the goal involves long-term engagement and tenacity. Extrinsically motivated engagement is related to extrinsic motivation [34], which is perceived through external incentives (e.g., money, grades, recognition, and avoidance of penalty). This form of engagement is relatively simple to initiate but difficult to sustain over time. Intrinsically motivated engagement, on the other hand, derives from intrinsic motivators [35, 36, 34], such as challenge, curiosity, and cooperation, which contribute to the individual's true enjoyment and satisfaction while completing the activity. As a result, intrinsically motivated engagement is more likely to persist and potentially facilitate the individual in achieving the flow state [25], in which they are entirely engaged in the task.

The utilization of gaming elements offers good examples of motivated engagement. A substantial body of study has proven that gamifying can have motivators that keep people interested for lengthy periods. Researchers have made attempts to adapt game elements to educational interventions [12, 37, 38, 39]. Gamification is the technique of adapting game design aspects to non-game environments [10]. Developing motivational tasks is an art form that has been published for decades. However, there is a research gap due to a lack of gamification from an education perspective, which has specific challenges and efficient integration of learning-related ideas. Designing an educational task that fulfills the potential of intrinsic motivation and the learning process is highly demanding and can be facilitated by education. Many identified motivators are abstract and may be challenging to apply in practice. To ease this, previous research has produced design principles, many of which can be connected to the motivators mentioned in the literature. The motivators were synthesized from the taxonomy and introduced in this dissertation as follows:

- **Challenges:** Challenge is a motivator that emerges when the individual is presented with a task suitable to the individual's ability level. This motivator is the key to achieving a flow state, which may contribute to increased self-esteem [35]. As long as the challenge is fair to the individual's skill, it can be a tremendous motivation.
- **Control:** The control motivator emerges when the individual is given the freedom to influence educational activities. This motivator is the key to achieving a flow state. The term is analyzed two-fold: the individual's ability to reduce choice in tasks; and the input mechanism through which the individual with the task. Doing the learning task should be a secure and comfortable experience to ensure that learning tasks do not present a risk.
- **Curiosity:** Curiosity can be sparked by various circumstances, including a desire to explore every area and understand more about the teaching content. Curiosity can be triggered by involved activity that displays conflicting information, for example, enhancing the individual's need for knowledge. This motivator is prevalent in modern educational components that are often taken interaction and progression into account.

Teemu et al. provided a summary of design principles that promote learning. Beginners and experienced individuals should all be able to approach a game easily, so all are offered fair prospects of progressing in the activity [8]. Consequently, the activity should motivate individuals even when they are encountered by sophistication [40]. This principle relates closely to the challenge, in which suggestions on creating challenges suitable for different players are needed. If a challenge is overly complex, it may demotivate the individual, thus resulting in decreased engagement. A task that repeats similar challenges may eventually become boring; adding variation to an educational assessment nurtures curiosity. However, introducing the loss scenario provides a sense of pressure. The rationale is that the individual becomes more engaged in the task to avoid loss. This promotes the tension and thrill in which the individual must perform an action and drive an effort to achieve a learning task within a given time frame (or resources). Moreover, designing scaffolding in educational environments provides empirical support for learning practices that improve effective learning. This enhances the individual's perception of control during the learning process, in which many implications were suggested [8]. The educational assessment must provide feedback when it is provided on performed challenges objectively, thus contributing to the subjectivity of control [41]. To support the learning process, it is essential to provide the individual with various means, such as alternative paths to achieve the task [42], various contents [40], and appropriate options to do so that may sustain the perceptiveness of control [43, 44]. Perceived challenge and control during learning tasks can become a good motivator, especially for learning purposes in an educational context, such as knowledge improvement and skills acquisition.

2.3 Educational Assessments

An educational assessment can help improve learning motivation in various ways [45]. The current literature and finding prospects of testing and educational assessment offered a state-of-the-art review, summarizing, and relevant research over the last decade. This is because, compared to other learning strategies, educational assessment results provide a critical evidential basis for high-stakes decisions, demonstrating its effectiveness in enhancing long-term outcomes of learning acquisition and facilitating mastery of new information. In these classroom investigations, students in the intervention condition took regular quizzes by recalling or using studied material to solve new problems, and quizzes were presented in various formats, including true-false, multiple-choice, and fill-in-the-blank. Chunliang Yang et al. addressed essential points about the testing effect, which focuses on how to sustain and enhance the motivation to learn [1]. Numerous studies have provided supporting evidence for the motivation explanation. For instance, class quizzes improve engagement in terms of attendance [46]. Pop-up quiz encourages individuals to prepare and concentrate on the class contents, which promotes the motivation to learn [47]. Another scholar found that testing and quizzing induce high expectancy, which fosters test performance [48]. A report from Struyven et al. found that if individuals perceive the assessment process as fair and free of subjectivism, this will significantly positively impact their motivation to learn [49].

Much study has been given to finding the best methods to measure learning [50, 51, 52]. Taking a test also results in learning, and several research studies have been conducted to optimally use multiple choice questions to improve long-term outcomes and develop more comprehensive knowledge. In this review, we align the analysis of the example paradigm in educational evaluation for learning. This dissertation recommends two approaches: quizzing and multiple-choice questions (MCQs). The recommendations from these two conceptual practices are nearly unanimous. The following sections are tracked with a description of relevant research that helps to explain why it is also a best practice for learning. The following sections are labeled with a description of relevant research that explains why it is also an excellent practice for learning.

2.3.1 Quizzing

Retrieving information from memory or recall has repeatedly been demonstrated to drive long-term outcomes in educational settings, namely testing effect [7, 45, 1]. Quick and easy recall of subject knowledge is vital to allow learners the cognitive space they need to construct complex arguments. One of the essential strategies for achieving such fluency and cementing domain knowledge is to practice recall regularly. With a series of carefully selected questions, it can easily demonstrate the grasp of the core concept and decide whether individuals' understanding needs a quick tweak. Quizzes also provide excellent formative information for instructors and activate the testing effect.

The testing effect has been the subject of a century of study. The consistency and development in understanding the effect may require customization. Even when compared to repeated restudy of the content, testing usually delivers a benefit, and this is undoubtedly relevant for prolonged exams [5, 7]. Testing provides retrieval practice on knowledge via low-stakes quizzes that contribute little or nothing to an individual's course performance. This approach has been used in classroom instruction to test students' understanding and issue grades. It improves performance in educational contexts due to its ability to retrieve information. The quiz also serves two main functions: first, testing (especially with feedback) improves learning and retention, and second, the metacognitive use of tests allows individuals to inform themselves about what they learn and do not learn so that they can focus on the future study efforts on the specific information [1].

In recent years, technology has played an essential role in education, and the application of game-based learning in the classroom has grown in popularity. Many game-based learning tools and platforms are built on the quiz concept [53, 15], in which students can earn points by choosing the correct answer from a list of options.

Incorporating game elements into learning sessions have developed a strategic notion of game-based learning and gamification. Quizzing is the best way to employ gamification, using one type of test and evaluation that aids teachers and educators in understanding knowledge acquisition [54]. Quizzing is a low-stake test that can enhance learning performance and help students retain their motivation. Its nature allows individuals to be engaged in the learning process and enhances learning outcomes by increasing motivation [55]. The benefits of quizzing can be demonstrated by varying the frequency and timing of quizzes to establish significant learning improvements and student achievement before and after a lecture [56]. Gamification in quizzing has been investigated to determine its relative effectiveness [57], its effects as an enabler of children's interaction and learning performance [58], its improvements in engagement [9, 59, 60], and its impacts on short-term assignments [27]. However, the gamification effects in long-term and classroom settings could be more evident since it may encourage various behavioral changes. Therefore, gamification requires a practical design that is dynamic and customizable [61, 62].

2.3.2 Multiple-Choice Questions (MCQs)

The multiple-choice questions (MCQs) have a long history, originating from early efforts to measure intelligence, and were later used in education to create a fair, equitable, and norm-referenced assessment scheme. They have been widely adopted in various educational and knowledge assessments due to their standardization, equity, and reliability. MCQs can test factual recall and cognitive functions, including critical skills and reasoning, and also stimulate learning. As such, significant research has been conducted to explore the best ways to use MCQs to assess learning. It signifies that the MCQs are suited to summative standardized and national examination [63, 64].

MCQs are composed of two parts: a stem, the question, problem, or task to be responded to or solved, and a series of alternative responses or alternatives, which are possible solutions to the question. The options are the correct answer, known as the key, and one or more wrong or less acceptable answers, known as the distractors. The essential weakness of this format is that high-quality questions are challenging to construct item stems, plausible and functional of correct options (keys) and (incorrect options (distractors) [65]. There are different types of multiple-choice questions based on the number of options provided in the test, ranging from two to, at most, five options. Depending on the outcomes, respondents will be confronted with a more significant number of plausible distractors and a more challenging situation.

The major flaw of the MCQ format has addressed an issue due to low validity, testing factual knowledge rather than a high level of cognitive knowledge, increasing the guessing effect (especially as the number of options decreases), and requiring more time in test development, particularly regarding finding plausible distractors. Most of this study has been on assessment challenges, such as enhancing the reliability and validity of multiple-choice examinations by removing non-functional distractors, reducing the guessing effect, and eliminating potential sources of confusion. Researchers have identified several best practices by synthesizing the outcomes of these studies to provide practical recommendations for educators [29, 30].

Given that multiple-choice testing promotes and assesses learning, it is essential to consider whether the best assessment methods correspond with the best learning practices. The alignment of best practices between these two testing aims is far from certain. Its potential for investigating how to best employ multiple-choice assessments to improve long-term outcomes and develop deeper comprehension has been developed. The following sections explore whether there is an alignment between best practices in using multiple-choice questions for assessment and learning. This dissertation follows a description from two primary relevant research that helps to explain why it is also a best practice for learning.

Each multiple-choice question must differentiate between individuals who have yet to acquire the skills and knowledge needed to measure learning successfully. When this psychometric goal is achieved, it is most often achieved in moderately challenging tests that push learners while also allowing them to succeed. Because there is a relationship between an item's difficulty and its discriminability, moderately challenging tests are appropriate for gauging learning. The optimal difficulty level is somewhat higher than the middle point between chance and perfect success; for example, for a three-option multiple-choice item, chance performance is 0.33, while the difficulty level that maximizes item discrimination is 0.77. [66]. Therefore, it is ideal for producing tests of moderate difficulty in order to facilitate learning. The main reason is that individuals may benefit when they use their knowledge to respond correctly. At the same time, they will be able to learn if they respond correctly. Straightforward multiple-choice questions can undermine the positive effects on learning because students can succeed without processing the information.

In contrast, tough questions can adversely affect learning because individuals cannot overcome challenging tasks. The key to providing difficulty is to allow multiple-choice questions to engage individuals in the cognitive processes required to gain the intended knowledge or skill. One example is incorporating game components such as gamification and effective methods to facilitate short-term and long-term learning potential, [67, 68, 69]. Scaffolding minimizes frustration associated with complex tasks by providing learners with advice on achieving them [70]. When individuals are challenged, learning should be scaffolded, and feedback should be provided. Finally, there is broad agreement in the assessment and learning literature about the ideal approaches for developing and providing multiple-choice tests.

2.4 Learning Process and Its Theoretical Concepts

The aim of this study is to establish a conceptual framework that represents the optimal learning process through the integration of theoretical concepts. Examining the learning process in educational assessments through the integration of theoretical concepts is crucial in fostering an effective educational environment. This dissertation focuses on the examination of theoretical concepts from both objective and subjective perspectives and the evolution of educational assessments. Figure 2.1 illustrates the overall theoretical concepts employed.

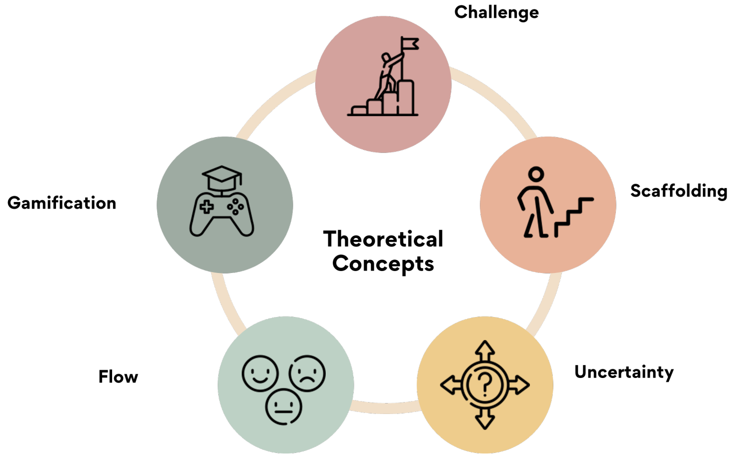


FIGURE 2.1. Theoretical concepts we employed in this study.

2.4.1 Challenge-based Gamification

Challenge provides the driving action behind the game. According to Bedwell et al., The term "challenge" refers to both the display of difficulties in a game and the nature and complexity of such tasks [71]. The game's difficulty, the nature of the difficulties given to individuals, and the degree of uncertainty inherent in characterizing these problems are all gaming challenges. The adaptation, challenge, conflict, and surprise attributes are all included. In order to provide an optimal experience of high engagement and fulfilling experience, the degree of challenge should automatically vary according to the individual's skill level.

Providing good assessment tools is essential in any learning environment. The challenges of an educational assessment and activity should be cognitive to stimulate cognitive curiosity and facilitate the individual's knowledge and skill acquisition processes. The tasks should challenge the player to the extent of their abilities while avoiding challenges that are too easy or too difficult [72].

Gamification introduces a method of incorporating game mechanics and applying them to the non-game context to elicit user engagement and satisfaction. Several definitions of gamification have been widely addressed in many domains, generally considered as applying game-based thinking through intrinsic and extrinsic motivation to enhance the overall performance of and engage the users [10, 73, 8, 12, 14]. Gamification is rapidly being used in educational contexts to boost student motivation and learning outcomes [27, 73]. Nevertheless, while research on the usefulness of gamification in education is advancing, there are gaps in the literature on which types of gamification could be beneficial for specific educational contexts. The theory of gamified learning proposed by Landers [17] stated that "game characteristics influence changes in behavior". This premise has been expanded to numerous situations, and especially in the educational context, for instance, in a training program [74] and in an educational environment [75] to support learning engagement and potential relevance.

The conceptual framework of gamification mostly comprises three main game design elements: the dynamics, mechanics, and components of the game (Table 2.1) [10]. To increase learning outcomes in many educational sectors relating to statistics and stem education, challenge-based gamification (i.e., points, levels, challenges, and leaderboard) can be effectively mixed with traditional teaching techniques such as lectures and quizzing [69]. Thus, gamification designers should consider students' profiles, as our findings reveal that advantages vary depending on the qualities of the students.

The potential of gamification has been used to improve education, where its implementation must demonstrate an improvement in incentive, as a short-term consequence, and learning outcome, as a long-term consequence [27, 73]. Challenges in education have continuously been addressed by integrating gamification. However, a gap between learning and engagement remains for game design principles in order to support learning and engaging environment. In

TABLE 2.1. Game design elements adopted from [10]

Dynamics	**Mechanics**	**Components**
Constraints	Challenges	Achievements
Emotions	Chances	Avatars
Narratives	Competition	Badges
Progression	Cooperation	Collections
Relationship	Feedback	Unlockable Contents
	Resources	Leaderboards
	Rewards	Dashboard
	Turns	Levels/Tiers
	Win-Lose Status	Points/Scores
	Exchange	Virtual Goods

this context, the author aims to summarize that optimal learning conditioning occurred when game elements and mechanisms are well-designed.

2.4.2 Gamified Learning Theory

Gamified learning theory provides a theoretical framework for analyzing the influence of gamification approaches on learner behaviors and attitudes, as well as the effect of these behavioral and attitudinal changes on learning [76]. It facilitates and controls processes that link specific game elements to learning outcomes. This theory highlights two mechanisms by which gamification can influence learning outcomes: mediating and moderating. First, it was proposed that gamification influences learning through a mediating process in which gamification alters a psychological trait, influencing a result of interest ($D \to C \to B$, as shown in Figure 2.2). For instance, the experience of time pressure may be used in a learning activity to produce a sense of challenge (to reflect the real-world task better it is modeled on), and the experience of time pressure could promote the transfer of acquired abilities beyond the classroom. In this case, the use of challenge must successfully produce the feeling of time pressure, and the experience of time pressure must lead to improved transfer for gamification to be judged successful.

Second, it was proposed that gamification influences learning through a moderating process in which gamification affects a psychological trait that increases the link between instructional content quality and learning outcome ($D \rightarrow C$, which moderates $A \rightarrow B$, as shown in Figure 2.2). For instance, novelty may encourage learner engagement and increase motivation to focus on the instructional content. In this case, the game narrative must successfully improve learner engagement, and learner engagement must deepen the link between instructional content and results.

Researchers attempted to evaluate the impact of gamified learning theory several times. Locke and Latham summarized the goal-setting theory to explain how to motivate individuals to perform better in challenging tasks by setting and monitoring goals [77]. More particularly, the two core findings from empirical studies that led to the development of goal-setting theory were: 1) There is a linear relationship between the degree of challenge and performance, and 2) Challenging goals lead to higher performance than no goals at all. Thus, this theory posits that optimal performance is achieved when goals are purely objective and moderately complex. A conceptual framework of gamification in gamified learning theory is shown in Figure 2.3.

Since the gamified learning theory states that gamification does not affect learning directly but stimulates a learning-related behavior in a process. The empirical study linked game elements with focal learner behavior and time on task by exploring educational research on competition and psychological research based on goal-setting theory [76]. They found empirical evidence that gamification can be used successfully to affect targeted learning-related behaviors. Thus, the game elements can provide learning outcomes with a solid basis for the theory of gamified learning. Another study investigated the role of learning tendencies in the gamification process concerning performance and engagement [78]. The findings hold that sound instructional design is key to successful learning, and balancing the environment to keep engagement and mastering are essential. Gamified elements must be developed in such a way that they address particular learning behaviors of all students in order to produce a balanced gamified environment.

Proposition 3 from the theory of gamified learning proposed by Landers [17] states that "game characteristics influence changes in behavior." Changing game elements may encourage student behaviors throughout the activity, and it can reflect the impact of engagement and learning progress. A more explicit objective might boost motivation to learn. The effect of behaviors reflects substantial differences in learning, in which individuals may put cognitive effort into their learning. Engagement in such approaches is a good focus behavior. Thus, gamification that delivers game rewards for allowing learners to adjust the frequency of metacognitive prompts is likely to enhance learning.

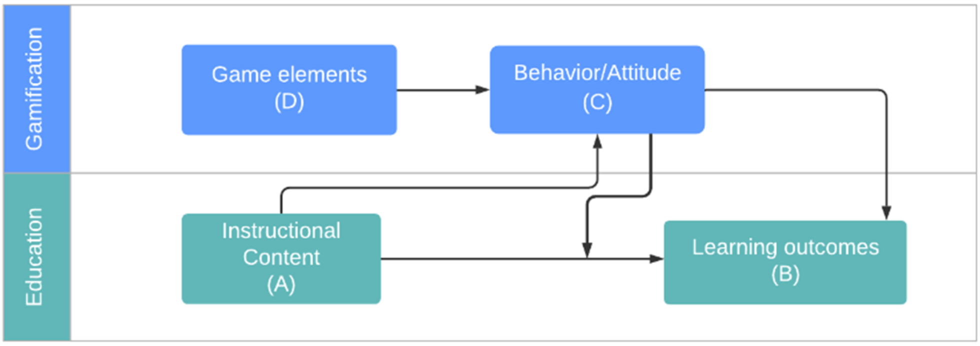


FIGURE 2.2. Theory of gamified learning: $D \to C \to B$ is mediating process, $D \to C$, which moderates $A \to B$ is moderating process [17]

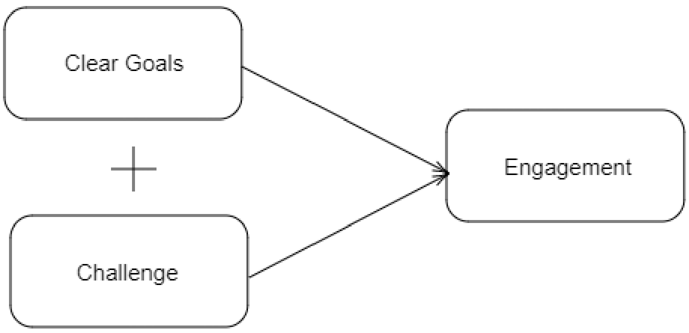


FIGURE 2.3. A conceptual framework of gamification in gamified learning theory [77]

2.4.3 Flow Theory

Flow has been the center of Mihály Cskszentmihályi's research in various contexts. He defines flow as a zone of full engagement and effortless action that occurs when an individual is in harmony [25]. It is associated with engagement and gamification, also known as optimal experience. Based on the recent literature, the minimum conditions for a task to lead an individual to a flow state should balance the challenge level and the ability required for the person to complete the task. In the first model, Csikszentmihalyi describes seven emotional states related to flow (as shown in Figure 2.4). The theory simplified that three states exist for learning: boredom, flow, and anxiety [79] (see Figure 2.6). [80] developed an alternative model (see Figure 2.5) in which the flow state of each individual varies. The flow state level can be higher or lower at different moments of the activity. The study postulated that people can dynamically change their states over time.

As a learner progresses through a task, one's flow state is more likely to be maintained if the challenge increases to match the developing abilities. Likewise, the "boredom zone" will emerge if the challenge does not grow as the learner's abilities. In the boredom zone, the individual is uninterested in the task and quickly disengages from it. Alternatively, an individual may experience dissatisfaction if their ability level is insufficient to cope with the task's intrinsic complexity. The tasks in the anxiety zone may be of interest to her or him, but the task gets challenging, and they lose motivation to pursue it. In many circumstances, individuals start a new task with a gap in their knowledge and limited abilities. Consequently, their task should match an optimal challenge level to maintain within the flow channel [25, 81].

Flow is essential in education since it is a motivator for learning. To maintain flow, we must continually improve our abilities to confront greater levels of challenge. Achieving flow gives us a sense of accomplishment since being in flow signifies that we have consistently achieved a task. Csikszentmihalyi established the aspects of flow to characterize an ideal experience as the theory progressed. One aspect is achieving a balance between the level of difficulty and ability [25]. Beginners and more experienced players might become involved when faced

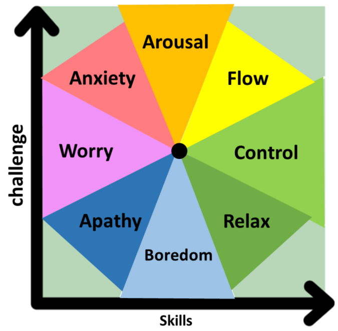


FIGURE 2.4. An original flow model proposed by Csikszentmihalyi [25]

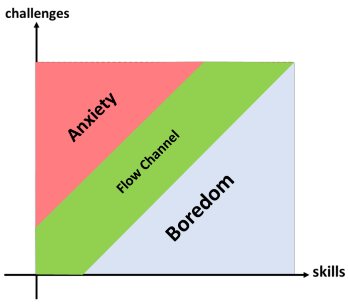


FIGURE 2.5. A simplified flow model proposed by Sharek [79]

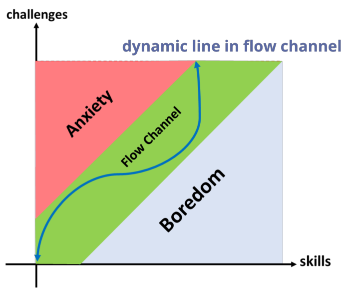


FIGURE 2.6. An alternative flow model proposed by Schell [80]

with a challenge that needs proper actions on their side to meet and rewards them with a sense of competence when they succeed. Csikszentmihalyi and Seligman highlight the importance of a close match between challenge and ability [82]. This state necessitates the development of a certain level of ability.

Balancing challenge and ability for each student in a classroom with varying degrees of ability becomes a problematic endeavor. Educators can use a variety of personalization approaches to achieve this. Several studies have proposed educational options for increasing or decreasing the difficulty of a task and allowing them to tailor the task to their ability [83], while another study emphasizes the importance of making individuals aware of their capabilities and pushing them to apply those abilities to whatever problems they face [82]. They are competent individuals confronted with a learning challenge and use their positive abilities in the learning process. There is a consensus among scholars that explore the extent to which gamification can improve learning outcomes within higher education [84].

Flow, following gamified approaches, begins with identifying and elaborating on one's goals, followed by the development of concrete targets to fulfill those objectives [85, 86]. According to research, there is a direct link between higher levels of engagement and the introduction of gamification to learners in online courses [87, 88]. With these premises, the theoretical doctrines of flow theory align well with gamified approaches to learning.

2.4.4 Zone of Proximal Development

Currently, most game designs provide the ability to adjust the difficulty level according to the player, and individuals may tackle increasingly tricky challenges with higher levels of skills [68, 89]. However, the existing studies did not provide comprehensive guidance for educational purposes. The claim that traditional testing needs to be extended by assisted performance has significantly impacted the assessment practice, including dynamic assessment and adaptive systems.

Vygotsky provided us with a theoretical framework and recapped it in [23], the Zone of Proximal Development (ZPD), to help us understand and assist in learning [91]. With the appropriate guidance, learning will be more effective in this Zone of Proximal Development. ZPD is characterized differently in various contexts. The motivational and creative aspect of learning is emphasized in development supported by doing a task or play. This illustration depicts the zones of proximal flow, where the zone of proximal development is located between the flow and anxiety zones. The central elaboration is to determine the relationship between learning and development, as the learning process leads to the outcome of achieving

FIGURE 2.7. A transition of learning in the context of the zone of proximal development adopted from [23]

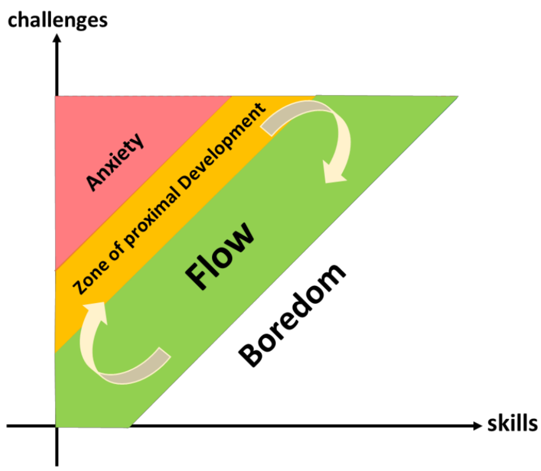


FIGURE 2.8. A conceptual zones of proximal flow adopted from [90]

tasks. Lev Vygotsky originated the idea of the zone of proximal development, which refers to the difference between what a student is capable of performing independently and what they are capable of achieving with guidance and support (see Figure 2.7 [23]). A large variety of interpretations is related to the flow theory as shown in Figure 2.8 [90]. Vygotsky believed that an individual is in the zone for a particular task, providing support will enhance the learning process and boost a chance to achieve the task. There are three essential components that aid the learning process:

- The presence of knowledge and skills is beyond that of the individual.
- Social interactions with expert support allow individuals to observe and practice their abilities.
- Scaffolding supports the individuals as they are directed through the ZPD.

In the literature, ZPD has become synonymous with scaffolding. Researchers stated that scaffolding is a procedure that enables a novice to accomplish a task or reach a goal beyond his independent efforts [92]. They identified specific processes that contribute to effective scaffolding; maintaining the individual's interest, making it simple, emphasizing certain aspects, lowering frustration, and demonstrating.

Scaffolding is another critical component of the ZPD hypothesis to achieve the key objectives and can be linked to the education context [23]. Verenikina adopted the word scaffolding to operationalize the concept of teaching in the ZPD [93]. Scaffolding is used in the context of the ZPD to illustrate the social and interactive aspect of instruction and learning that occurs in the ZPD. Scaffolding aids the learning process by providing support to the individual. Scaffolding is frequently lowered throughout the learning process so that the student becomes self-sufficient [94].

Several lines of evidence suggest that scaffolding plays the role of education to provide individuals with experiences in their ZPD, encouraging and advancing their learning. According to [95], when individuals advance through a task, instructors can use a variety of scaffolding to facilitate individuals' different levels of ability. Some common scaffolds and ways could be used in the classroom, including cues, hints, and prompts. The evidence was synthesized by experimenting with observing learning when individuals were given scaffolding, which resulted in better than a traditional classroom activity [96]. Scaffolding in the classroom can include demonstrating competence, providing hints or cues, and adjusting content or task [97]. Another study allows the participants to request and ask for support by hints and keep individual effective learning to struggle with novel difficulties [98]. Several noteworthy articles have advanced theoretical understanding of the ZPD in relation to instruction [91, 99, 100, 101].

The studies presented thus far provide the benefit that scaffolding can promote learning by motivating learners how to learn, providing a comfortable learning environment, and engaging learners in a meaningful and dynamic scale. Through this learning experience, individuals can be enabled by challenge and progress into deep learning and discovery of such information. ZPD concept turns the link between development and learning on its side, and the critical element of learning is that it generates the zone of proximal development, which is a necessary component of development and can result from learning. This theoretical concept could identify the presence of the learning process.

2.4.5 Prospect Theory

Prospect theory (PT), developed by Kahneman and Tversky, is a theory of behavioral economics and finance that is based on the idea of loss aversion [102]. This theory highlights that individuals perceive losses more acutely than equivalent gains, and their preferences are influenced by the framing of the problem. When presented with a decision between equal possibilities of gain or loss, most people avoid making the decision due to the fear of loss outweighing gaining satisfaction. The framing effect on MCQs can impact the risk tolerance of individuals, leading to preferences that depend on the presentation of options. For instance, if options are presented as gains, individuals become risk-averse, while they become risk-seeking when options are presented as losses. In the context of education, this theory can be applied to improve student's learning outcomes by designing assessments that consider the framing effect. Understanding how students perceive risk and potential loss or gain can help educators tailor assessments and feedback to increase motivation and engagement. By taking into account the principles of PT, educators can promote a positive learning experience and help students achieve better outcomes.

Prospect theory, as a foundation of behavioral economics, provides a crucial theoretical surface to the developing discipline of decision-making. Decision-making often occurs in the context of imperfect knowledge. To reason about uncertainty, we can adopt probability theory as a language. Prospect theory has some similarities to the concept of the expected utility function. Similarly, the value function was derived from the expected value [103]. The normative decision model assumes that expected utility exists independently of probability. Utility is defined in a chance game as the point of indifference between an inevitable and uncertain outcome. In summary, utility is portrayed as a subjective way of determining the significance of any given objective outcome to a specific individual. The human mind is not only sensitive to logic when evaluating gains and losses, but prospect theory also exposes these cognitive biases when it comes to decision-making [104]. When a person is faced with uncertain outcomes, rational people weigh the potential gains and losses to maximize utility. However, the potential of gains and losses is modified by two aspects, high probability outcome, and low probability outcome [104].

High probability outcome happens when people overweight outcomes that are considered certain, as opposed to merely possible outcomes. This scenario leads individuals to avoid risk when there is a prospect of a gain. It also contributes to individuals seeking risk, even when one of their options is a loss. Low probability outcome happens when people are overweight, with possible but not probable outcomes, and they overestimate their chances of occurring. At the same time, this scenario leads individuals to seek risk when there is a prospect of a gain and avoid risk when their option is a loss. The illustration is shown in Figure 2.9.

Prospect theory, under uncertain conditions, provides individuals with the likelihood of various outcomes and refers to cases in which the uncertainty is due to sources other than the decision maker [105]. For instance, in gambling, such as lotteries. However, the decision maker's uncertainty is rooted in internal sources in many circumstances. For example, the individual who must answer MCQs from a pool of all possible options means that people will encounter uncertainty as a result of insufficient or untrustworthy knowledge. Bereby-Myer et al. assessed the framing effect by considering individuals who gain partial knowledge in multiple-choice questions [106]. The experiment was conducted by allowing individuals

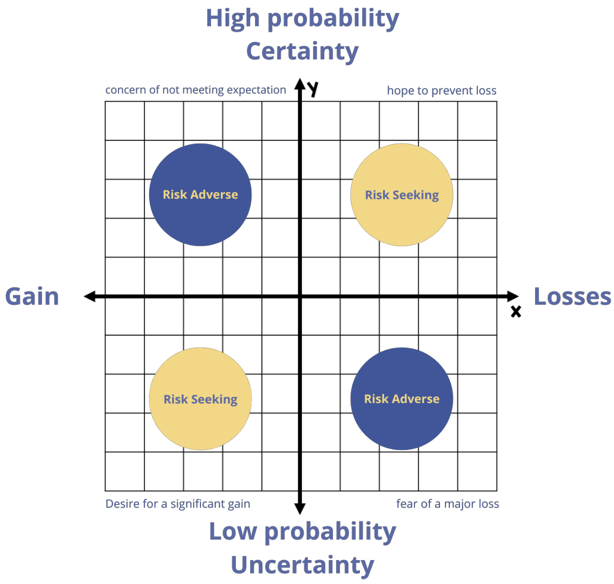


FIGURE 2.9. A relationship between probability and the potential of gains and losses adopted from [104]

took tests with different scoring methods. The inclusion of gain and loss in the scenario provides the framing effect, in which the result illustrates the alignment of behavioral change under uncertainty. This method was extended to determine the proper scoring method which optimizes the cumulative prospect utility [107]. The features of prospect theory were applied in Wu et al. which introduced a testing format that requires test-takers to express their degree of certainty on the response option they have selected, leading to an item score that depends both on the correctness of an answer and the certainty expressed [108]. The link between psychometrics and prospect theory was found, which verifies the possibility of using this theoretical concept in the area of multiple-choice questions.

2.5 Physics-in-Mind Perspectives

2.5.1 An Overview of Game Refinement Theory

A general model of game refinement, based on a logistic model of game uncertainty, was proposed by Iida et al.[109]. From the players' viewpoint, the information regarding the game result is an increasing function of time t (i.e., the number of moves in board games). Here, the information on the game result is defined as the amount of solved uncertainty (or information obtained) $x(t)$, as given by (2.1). The parameter n (where $1 \leq n \in \mathbb{N}$) is the number of possible options, $x(0) = 0$, and $x(T) = 1$.

$$x'(t) = \frac{n}{t} \, x(t) \tag{2.1}$$

where $x(T)$ is the normalized amount of solved uncertainty. Note that $0 \leq t \leq T$, $0 \leq x(t) \leq 1$. Equation (2.1) implies that the rate of increase of the solved information $x'(t)$ is proportional to $x(t)$ and inversely proportional to t. By solving (2.1), (2.2) is obtained. It is assumed that the solved information $x(t)$ is twice derivable at $t \in [0, T]$. The second derivative of (2.2) indicates the accelerated velocity of the solved uncertainty along with the game progress, which is described by (2.3). The acceleration of velocity implies the difference in the rate of acquired information during game progression. Then, a measure of game refinement GR is obtained as the root square of the second derivative, described by (2.4):

$$x(t) = \left(\frac{t}{T}\right)^{n} \tag{2.2}$$

$$x''(t) = \frac{n\,(n-1)}{T^n}\, t^{n-2} \mid_{t=T} = \frac{n\,(n-1)}{T^2} \tag{2.3}$$

$$GR = \frac{\sqrt{n\,(n-1)}}{T} \tag{2.4}$$

Let p be the probability of selecting the best choice among n plausible options. As such, the definition of gamified experience is based on the notion of the risk frequency ratio or risk-taking probability, which is defined as $m = 1 - p = \frac{n-1}{n}$ [26]. Then, the gamified experience is achieved if and only if the risk occurs with parameter $m \geq 0.5$, which implies $n \geq 2$. Knowing that the parameter n in (2.4) is the number of plausible moves, for a game with branching factor B and length D, $n \simeq \sqrt{B}$ is approximated where the GR is given as

(2.5): The GR measure has been adopted and verified in various games, as demonstrated by previous studies [110, 111].

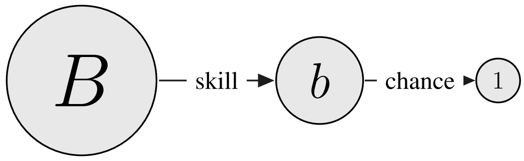


FIGURE 2.10. The player decision selection process

Any game can be transformed into a stochastic game with a smaller branching factor by skill. When the $\alpha\beta$ algorithm is incorporated in the minimax-based game tree search, it is expected to reduce the search efficiency significantly [112]. The best-case analysis enables to estimate the branching factor $b \simeq \sqrt{B}$.

$$GR_{board} \approx \frac{\sqrt{B}}{D} \tag{2.5}$$

For the scoring games, the GR measure is determined by 2.4. G stand for the average goals. Meanwhile, T is the total points or goals. GR is given as (2.6).

$$GR_{scoring} \approx \frac{\sqrt{G}}{T} \tag{2.6}$$

In this study, the solving rate is given as v and the solved uncertainty of the game $y(t)$ is an increasing function of time t, which can be described by (2.7). A player may feel informational acceleration, which is formulated analogically to the physics formulation of motion $y(t) = ut + \frac{1}{2}at^2$. Since u is the initial velocity at $t = 0$, then (2.8) is obtained. The intersection can be calculated at $t = D$ or $t = T$, where (2.9) is identified as the informational acceleration that describes the gamified experience and comfortable thrills under consideration.

$$y(t) = vt \tag{2.7}$$

$$y(t) = \frac{1}{2}at^2 \tag{2.8}$$

$$a = \frac{2v}{D} = \frac{2v}{T} \tag{2.9}$$

Sophisticated games possess an appropriate game length to solve uncertainty while gaining the necessary information to identify the winner [26]. This condition can be found at the cross-point area between (2.7) and (2.8), where $a = \frac{B}{D^2}$ is identified as the noble uncertainty zone ($\in [0.07, 0.08]$) of the $GR = \sqrt{a}$ (or $a = GR^2$), as previously found (Table 2.2).

TABLE 2.2. Various GR measures of several board games and sports [26, 110]

Game	B, G	D, T	GR	a
Western Chess	35	80	0.074	0.00547
Chinese Chess	38	95	0.065	0.00423
Japanese Chess	80	115	0.078	0.00608
Mah Jong	10.36	49.36	0.078	0.00608
Go	250	208	0.076	0.00578
Table Tennis	54.86	96.47	0.077	0.00593
Basketball	36.38	82.01	0.073	0.00533
Soccer	2.64	22	0.073	0.00533
DotA	68.6	106.20	0.078	0.00608

2.5.2 An Overview of Motion in Mind

An object is characterized by its mass in Newton's mechanics. A stronger (weaker) player has a higher (lower) skill to solve uncertainty in a game. This situation implies that the stronger (weaker) player would meet lower (higher) uncertainty during a game. Thus, a smaller (larger) value of mass (say m) is given to the stronger (weaker) player. Such a notion leads to the interpretation of mass in game playing (m), which corresponds to the magnitude of a player's challenge during a game. In the current context, v generally means the rate of solving uncertainty. In contrast, m implies the difficulty of solving such uncertainty(m = 1 - v). As such, both v and m are determined by the following [26].

Let B and D be the average number of possible moves and game length, respectively. Solving rate v is approximated as 2.10, by which v is equivalent with the slope v of game progress model in 2.7.

$$v = B/2D \tag{2.10}$$

Let G and T be the total number of goals and attempts per game respectively. Scoring rate v is given by 2.11, where the slope v of game progress model in 2.11.

$$v = G/T \tag{2.11}$$

Then, interpretation in the education context can be inherently conducted. As such, v and m are defined as the correctness rate or the rate of solving the question correctly (capability) and winning hardness or difficulty (challenge), respectively. Intuitively, velocity v is defined as v_0, namely "objective velocity", which the individual perceived game or activity experience by object.

The fundamental element was measuring the mass and velocity, enabling the derivation of force F, momentum $\vec{p}$, and potential energy E_p. Intuitively, Table 2.3 illustrates an analogical link that relates physics in mind notations and its in-game counterparts [26]. Based on such analogy, various motion in games can be determined, where the momentum, potential energy, and force were defined as (2.12), (2.13), and (2.14), respectively.

TABLE 2.3. An analogical link that relates physics in mind notations and its in-game counterparts [26]

Notation	**Physics context**	**Game context**
y	Displacement	Solved uncertainty
t	Time	Progress or length
v	Velocity	Solving rate
M	Mass	Solving hardness, m
g	Acceleration (gravity)	Acceleration, a (thrills)
F	Newtonian force	Force in mind (move ability)
$\vec{p}$	Momentum	Momentum (move intensity)
U	Potential energy	Potential energy, E_p (move potential)

$$\vec{p} = m \cdot v \tag{2.12}$$

$$E_p = ma \cdot y(t) = ma\left(\frac{1}{2}at^2\right) = \frac{1}{2}ma^2t^2 = 2mv^2 \tag{2.13}$$

$$F = ma = (1 - v) \cdot a \text{ and } a = \frac{B}{D^2} \tag{2.14}$$

Previous works [112] showed that $\vec{p}$ represents the player's growth rate determined by the different game depth and change over time. In this paper, $\vec{p}$ signifies the users' capability to play the game. In the game process, the game's energy reflects the amount of the movement potential (curiosity) that the game may transfer to the player [26]. Based on move potential, its notion can be described as attractiveness toward players like a gravity. A certain amount of anticipation is required in a skill-based game so that that challenge contributes to the expected risk (a larger m). This situation implies more chance to progress in the game (high E_p), and anticipation decreases if the player acquires sufficient information; thus, the player perceives it as motivation to move (i.e., results in a desirable outcome).

In the context of motion in mind, [32] stated that motivation is associated with the potential energy (E_p), which addresses the weight of the play's progress and the player's expectation. Control and focus were associated with the velocity (v) and momentum ($\vec{p}$), which represent the rate of an individual's progression and activity, respectively. Additionally, challenge-based gamification was input to investigate the progression and performance of individual students. This can be considered the necessary factor for analyzing transition gamification regarding the motion-in-mind concept. Therefore, a conceptual model linking motion in mind to such psychological attributes based on previous studies was constructed, as depicted in Figure 2.11.

2.5.3 Variable Ratio (VR) Schedule

The highest response rate was discovered to be variable-ratio (VR) [33], indicating that regular and straightforward rewards for performing one thing are not the best strategy to elicit

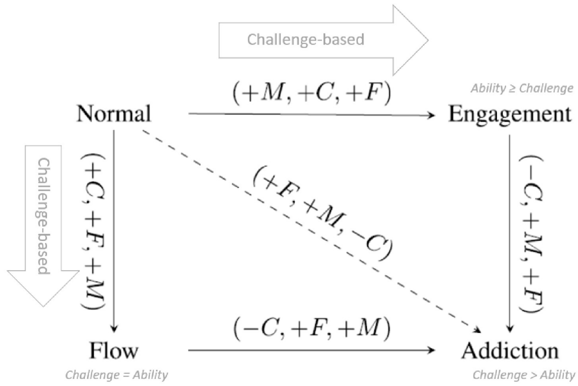


FIGURE 2.11. The conceptual model of engagement and addiction by [32] adopting challenge-based gamification

the intended behavior. The effectiveness of such a schedule can be increased by randomly changing the reward after various tasks.

In VR schedules, the parameter N shows the average reward frequency, where $1 < N \in R$. In this study, winning a game corresponds to obtaining a reward. It implies the game length, D in board games (total number of plies), and scoring games (total points or goals). Hence, $N = D$ or $N = T$, implying a general form of reward frequency of the game's winning rate. Based on such a notion, the winning rate v_0 and winning hardness m is defined by 2.15.

$$v_0 = \frac{1}{N} \ and \ m = \frac{N-1}{N} \tag{2.15}$$

This study adopts a MCQ paradigm based on the VR schedule to establish the link between learning and playing. This approach utilizes motion in mind measures to propose the underlying relationship between the VR schedule and the number of options N in the MCQ.

2.5.4 Objectivity and Subjectivity Measurement

It has recently focused mainly on a possible link between the motion in mind in several contexts [69, 113, 114], the goal is to find a link among all that the motion in mind may cover all theories as a grand unified theory. People's behaviors would tend to maximize the comfort in mind, which results in the establishment of a behavioral pattern as culture [32]. It indicates the area of comfort in mind in various of contexts based on the interpretation of solving hardness m to the player's ability k.

Considering the objective velocity v_0 and mass m, they are the winning rate for the objective and hardness rate, respectively. Velocity v_0 holds on the function of mass m, given by the equation $v_0(m) = 1 - m$, which k equals to 0 (i.e. perfect player). Based on the interpretation of solving hardness m to the player's ability k, the subjective velocity of the player (or individual) with ability level k is denoted mathematically as the following equation 2.16.

$$v_k(m) = (1 - km) \cdot v_0 \tag{2.16}$$

The subjective velocity v_k is varied by ability level k. The larger k means the player has less ability, while the smaller k means the player has a higher ability. As respect to mass m, the subjective velocity will become zero when the ability of the player holds at $k = \frac{1}{m}$. As the equation 2.13, potential energy E_p (or E_0) will be maximized at $m = 1/3$, so when considering typical board games like chess and Go, we reasonably assume $k = 3$. However, when considering sports games, $k = 4$ might be more reasonable. The illustration of motion in mind measurement has shown in Figure 2.12(a) and 2.12(b). Based on the interpretation of m to the player's ability k, the subjective energy E_k of the player (or individual) with ability level k is denoted mathematically as the following equation 2.17, representing the people's engagement from the subjective point of view,

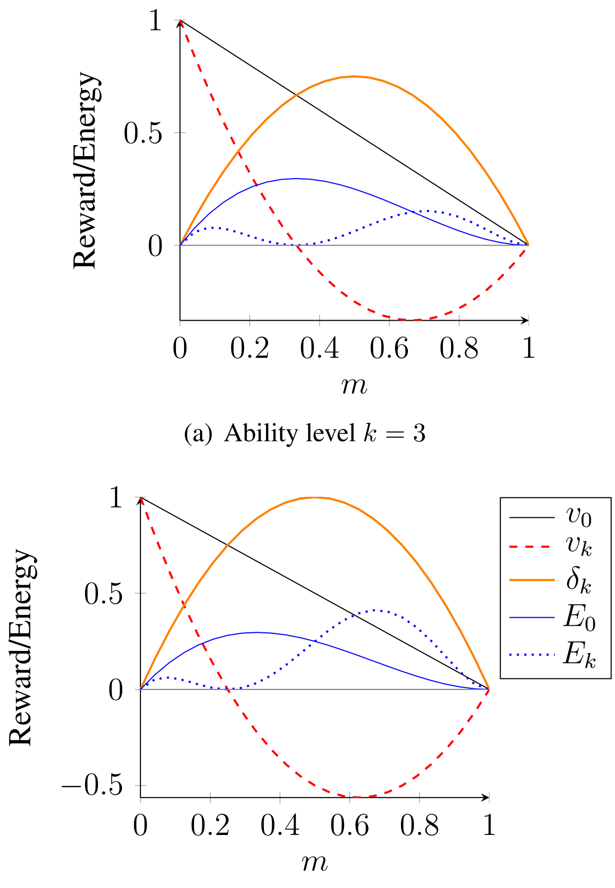
$$E_k(m) = 2mv_k^2(m) \tag{2.17}$$

The comfort in mind could be evaluated by the total energy in mind, namely E. Several comforts in mind in various contexts has been investigated while considering the mass m and new measurement Δ_k, which is given by the absolute difference between objective and subjective reinforcement. Masters and beginners should widely play the popular game at that time/era in its history. It postulates that the objective reinforcement meets the subjective reinforcement ($E_0 = E_k$) to be mass entertainment at $m = 2/k$, where m stands for the mass of the popular game under consideration. When assuming $k = 3$, the border is $m = 1/3$ and $m = 2/3$, respectively, which looks well-balanced (play comfort) in popular games such as Go, Chess, and Shogi. The reinforcement difference (Δ_k) can be depicted as curiosity. The motion-in-mind concept depicts three areas based on the mass criterion m. Conjecture 1 can be defined as the following:

CONJECTURE 1 (**Interpretation of m with respect to the reinforcement difference**). *The first one is the known (or solved) area $0 \le m \le 1/k$, where implementing fairness/equality is essential. The subjective velocity v_k would become zero when $m = 1/k$, where, Δ_k $(= E_0 - E_k)$ will be maximized. The second is the learning area $1/k \le m \le 2/k$, where people are roused to learn. The third one is the play (or emotion/entertainment) area $2/k \le m \le 1$, where people would enjoy their playing activities with specific emotions.*

One essential characteristic is that learning comfort holds the objective reinforcement E_0 dominating over the subjective one, so knowing the game-theoretical value or solving uncertainty is optimized. In the learning context, individuals would feel highly engaged at the peak of Δ_k $(= E_0 - E_k)$. It thus implies incorporating challenge-based gamification.

Then, motion in mind measures such as v_k will generalize δ_k, representing the competitiveness. People would feel comfortable at $m = 1/k$ due to full equality in society (social comfort) [113]. Smaller δ_k (high competitiveness) corresponds to less motion of game score or stable/deterministic. δ_k is maximized at $m = 1/2$ in every k where people would feel comfort due to its fairness, namely δ_k=0. Larger δ_k (low competitiveness) corresponds to the greater motion of game score or unstable/stochastic. It implies that a game depends on δ_k=kmv_0 (momentum of play) or the balance between skill and chance. By the way, a certain degree of competition may be incorporated and varied in each society. Then, inequality or disparity issue happens as well. The critical point is to use the difference between objective and subjective ones as measurement. The objective aspect is essential in the ordinary context, like the physics of Nature. At the same time, the subjective one is essential in mind perspective, but it cannot be measured in solitary. This implies why the difference would be employed as a reliable measurement.



(a) Ability level $k = 3$

(b) Ability level $k = 4$

FIGURE 2.12. Measures of motion in mind for $k = 3$ and $k = 4$

Moreover, when focusing on competition, we reasonably assume that society is less competitive than competitive games and that educational games or gamification would be intermediate between society and competitive games. Go and sports games would be typical examples, where mass m holds at $\frac{1}{3}$ to $\frac{1}{2}$ (approximately $k = 3$ and 4).The illustration of motion in mind for $k = 3$ and $k = 4$ as shown in Figure 2.12(a) and 2.12(b).

2.6 Chapter Summary

In this chapter, related work prior to the current dissertation was introduced. Works related to the essential keywords facilitate learning: challenge-based gamification, flow theory, zone of proximal development, prospect theory, and theoretical concepts in educational assessment.

With the entertainment aspects, a measure of objectivity and subjectivity to determine the learning comfort in the education context was introduced, namely motion in mind. These studies are significant as they serve as the base for the research carried out in this thesis regarding the impact of learning and the link between play and learning in the education context.

CHAPTER 3

Capturing Potential Impact of Challenge-Based Gamification on Gamified Quizzing

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This chapter is an updated and abridged version of work previously published in

- Punyawee Anunpattana, Mohd Nor Akmal Khalid, Hiroyuki Iida, Wilawan Inchamnan: Capturing potential impact of challenge-based gamification on gamified quizzing in the classroom, Heliyon, Volume 7, Issue 12, 2021, e08637 (IF=2.85). ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2021.e08637.

3.1 Chapter Introduction

This chapter outlines the results obtained from integrating challenge-based gamification into an elementary school classroom to examine the emergence of student engagement and learning-related behavior. The approach was applied to logical puzzle quizzes, where various gamification alterations were captured and analyzed using physics analogy, precisely the motion in mind notion. The mixed methods design experiment was constructed around the concept of time pressure and the difficulty of gamified elements in the quizzing process. By incorporating qualitative explorations using thematic analysis, this model was designed to validate and build on the quantitative findings using the motion-in-mind model. The findings suggested a potential integration of motion in mind and flow theory and its ties to engagement and learning as a new conceptual framework.

3.2 Gamification Designs and Elements

Comfort and pleasure are important for learning, as they can motivate learners to engage in new tasks and create a desire to repeat the experience [115]. Understanding how gamification affects behavior requires the consideration of concepts like motivation and engagement. Progression steps and engagement cycles, which provide constructive feedback and maintain motivation, play important roles in facilitating an optimal flow [116]. However, engagement can also have negative effects, such as relapse and withdrawal.

There are three methods of establishing challenges in a single-player game: fixed difficulty, gradually increasing difficulty, and difficulty balancing through computational intelligence. Fixed difficulty provides enjoyment but may not lead to skill development or engagement [117, 68, 15], while gradually increasing difficulty promotes engagement and improves learning performance [61, 62]. Computational intelligence adjusts difficulty based on evaluating player actions, creating an interactive environment that engages players at their skill level [67].

According to the gamified learning theory and gamification, the proposition has been extended to support the potential relevance of engagement and learning. Changing game elements may encourage student behaviors throughout the activity, and it can reflect the impact of engagement and learning progress. To summarize, challenge-based gamification may enable a student to complete more tasks with higher motivation, a higher sense of achievement, and a better understanding of learning progress. Those elements are analyzed through the motion in mind concept and flow theory. This study intends to focus on three challenge-based game mechanics: time pressure, points/scores, and levels.

TABLE 3.1. Integrated game design elements in the challenge-based gamified quizzing

Design Elements	Description	Purpose
Timer	Numeric measure of player's performance (time used)	Indicator of time pressure
Points, Scores	Numeric measure of player's performance (answer corrected)	Indicator of explicit reward
Levels	Difficulty level of quizzing provides the sense of progression	Indicator of progression and difficulty

3.2.1 Time Pressure

Time pressure refers to the uncertainty that influences individuals in terms of difficulty and challenges, whereas discomfort is caused by time pressure. Cycles, countdown, increasing pace, and timer are all examples of time pressure in games. The implications of time pressure on engagement are hypothesized to be as involved when time pressure is combined with objectives [116]. It has been used to motivate individuals to look for positive outcomes. Furthermore, the significance of uncertainty in how individuals are supposed to behave in response to unpredictable occurrences (and tasks) was highlighted. Time pressure can change individual behavior and positively and negatively impact performance, which senses potential learning and engagement.

3.2.2 Points and Scores

Points are a basic numerical feedback element that can be used to track progress, provide information about success in the task, and unlock additional features that encourage motivation. Points are also scores indicating performance by acting as achievements to provide positive reinforcement. To have a positive effect on learning, feedback needs to provide information related to the task or process of learning. It can do so through different cognitive processes, including confirming to individuals that they are correct or incorrect and indicating alternative strategies to understand particular information. Points and scores can be seen as extrinsic rewards for performing the task, which promote short-term outcomes.

3.2.3 Levels

Levels aid in mapping a user's development and progression by integrating various difficulty levels. It acts as a gateway to new challenges. The achievement/challenge-based game design is centered on overcoming difficulties, progressing and earning rewards, and achieving competence. For example, each learning objective should then be subdivided into smaller activities [118]. Individuals gain a wide range of enjoyment from games, including challenges and competition. The design stages with increasing difficulty increase arousal, whereas levels with greater variety and narrative structuring increase spatial presence [25]. Gradually rising difficulties further support the requirement for competence [80].

Table 3.1 describes the role of gamification components and design elements in this experiment, along with their summarized purposes for this study. The proposed framework in this study comprises three main layers: (a) gamification construct, (b) game design elements, and (c) assessment methodology which is used to capture the challenge-based gamification impacts and individuals' perception in engagement and learning aspects. The relationship between gamification objectives and game design elements is illustrated in Figure 3.1.

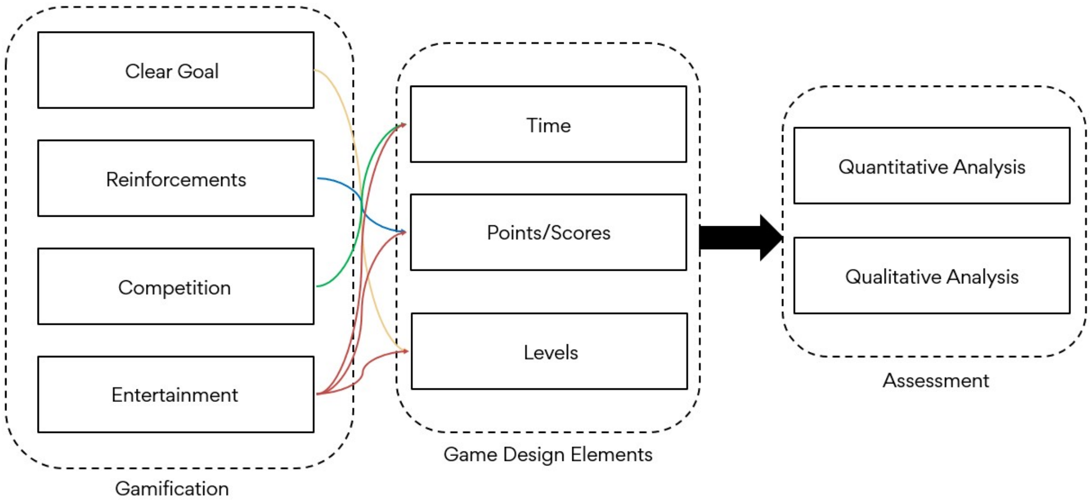


FIGURE 3.1. A proposed challenge-based gamification framework used in this study.

3.3 Related Works in Challenge-based Gamification

According to the long tradition in the educational context, thus far, there have relevant studies on challenge-based gamification combined with traditional pedagogy in this context. Most prior studies revealed that sophisticated activities and demanding elements could be used to engage students more deeply, therefore validating the hypothesis underlying the concept of flow [119]. The degree of difficulty of the activity has a major impact on user involvement and concentration. A challenge is one of the gamification mechanics used to motivate individuals to achieve a task and move forward in the learning process [68]. A challenge is a solicitation to engage in a difficult but achievable task. Uncertain outcomes are difficult to predict because of the user's answers, different goals, concealed information, and randomness [120]. Atreyi et al. showed that users were motivated to perform predetermined tasks, which assisted inexperienced users in learning how to progress [88]. This typically entails competency in relation to the core psychological demands identified by self-determination theory [121].

In a classroom setting, these challenge-based gamification merits were found to transform the learning situation into an engaging experience that encourages independence and self-competence (i.e., [122] partitions the game into many iterations). Other studies focused on the quality of education and evaluating the learning perceptions [13, 72, 123]. As a finding, engagement and performance were associated with the student's ability perception.

Many design principles have been proposed and categorized into several directions to identify an effective method to support the applicability of gamification [62, 8]. Challenge-based gamification may encourage an individual to complete more tasks with higher motivation, a higher sense of achievement, and a better sense of learning progress. Researchers found that the challenge design principle can more easily engage diverse players than other principles [68]. The relevant findings reveal that challenge-based gamification increases students' learning outcomes in a statistics course, contributing to our understanding of the impact of challenge-based gamification on measurement education and, consequently, gamified pedagogy. Another study [67] reported that the game's challenge had positive effects on learning and engagement. Likewise, the features of challenge-based gamification positively affect learning both directly and via increased engagement [89]. The results suggest that the game's challenge should be able to save up with the learners growing abilities and learning to endorse continued learning in game-based learning environments. The challenge element is a reasonably strong motivator that produces different motivational results that depend on the context of use. During the process, participants who attempted to tackle difficult questions also amplified their learning skills under pressure and reinforcement. Individuals felt relatively disengaged when the challenge level exceeded a certain threshold.

A challenge-based gamification is a design approach that incorporates achievement gamification elements positively associated with intrinsic need satisfaction to investigate its potential, motivate users, and significantly improve learning [124]. To summarize, challenge-based gamification may encourage a student to complete more tasks with greater motivation, a greater sense of achievement, and a better understanding of learning progress, with those elements producing promising results in terms of individual motivation and learning outcomes when used following proper design guidelines.

3.4 Experimental Setup

This dissertation designed an experiment to perform a challenge-based gamified assessment quiz system via Kahoot! to analyze the behavioral outcomes. In the experiment, the time pressure factor was first exerted by adjusting the time for each question. Then, the difficulty was adjusted based on predefined settings. Finally, an adaptation of patterns that randomized difficulty distribution and subgoal distribution were conducted. The behavioral changes among the various settings of the quiz were observed.

3.4.1 Mixed Methodology

This dissertation used mixed-methods research: quantitative data (gamified quizzing) acquired in the first stage was supplemented with qualitative data (interviews) in the second stage. Both quantitative and qualitative research topics were studied and validated through the use of a triangulation design: validating quantitative data model, in which information is administered continuously and separately without correlation. However, this method design was founded on the dominant-less dominant design, in which the quantitative approach takes precedence over the qualitative method. This model was applied to validate and expand on the quantitative findings by incorporating a few qualitative explorations.

Quantitative study data were collected from the experimental process via the metrics mentioned in section 3.5.1. Qualitative data were collected to determine the depth of view in engagement and learning improvement in the gamified quizzing context mentioned in section 3.5.2. Interviews were randomly conducted among the participants, forming the independent and dependent variables, respectively. Neither type of data collection interfered with the other

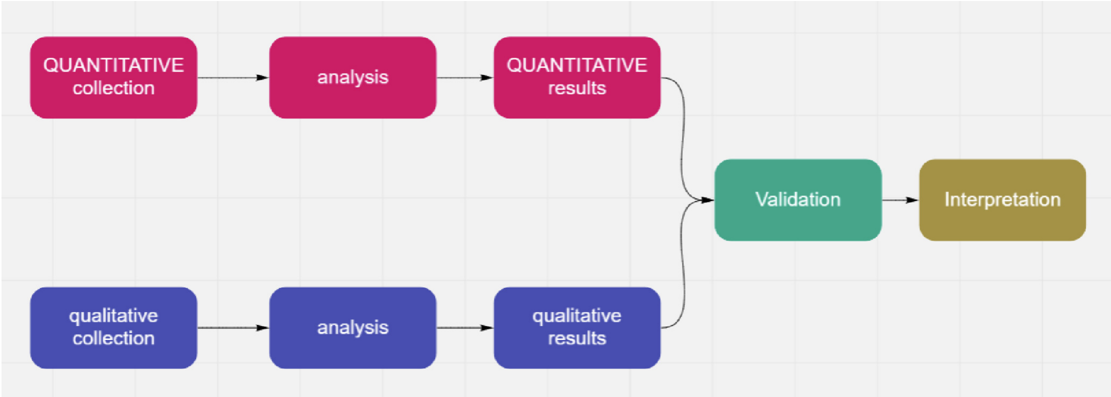


FIGURE 3.2. A triangulation mixed-methods design. We adopted this research design to support the three experiments conducted in this study. The first experiment involved applying the time pressure factor, followed by difficulty adjustment in the second one. Thirdly, an adaptation of patterns that randomized difficulty distribution and subgoal distribution was conducted for the third experiment. Finally, these experiments were supported by another layer of assessment procedures, as described in Section 3.4.4.

in the study, and the data were analyzed separately. Finally, the data were associated in order to respond to the research inquiries. Figure 3.2 displays the triangulation methodological process in this study [125].

This dissertation chose to employ this design to integrate the varied strengths, as well as the non-overlapping shortcomings of quantitative and qualitative methodologies [126] and to triangulate the methods in order to compare and resolve discrepancies between qualitative and quantitative findings directly [127]. Quantitative data was gathered to validate our theoretical hypothesis, which was established using qualitative data. Second, this design was used to get insight into the perspectives of the same relationships. A qualitative investigation was conducted to provide insights that complemented the quantitative data findings. As a result, the mixed method is described as developmental and complementary.

3.4.2 Variables and Participants

The purpose of this study is to investigate the impact of using Kahoot! in engagement and learning from the point of view of a researcher in the context of quizzing in education. This study indicated the variables to present the explanation data obtained from the experiment.

The independent variables were the challenge intervention adjustment: time pressure, quiz difficulty, and gamified adaptation. Correctness (number of right answers during the session) and achievement time were the dependent variables (amount of time used during the session). To evaluate student engagement, these factors were analyzed using motion in mind. As a result, another dependent variable was student engagement in the quizzing.

A total of 120 Thai elementary school students ($n = 120$) from five different classes participated in this study. The students aged between 7 and 12 years were asked to take the gamified quiz during class time. All participants ($n = 120$) were assigned the same experiment of three challenge-based gamification in this research. They were voluntarily recruited with a declaration to find the participants whose qualifications matched the study, and their written consent from their guardians was obtained. In this study, we followed the principles that all participants must be informed and highlighted all the negative and positive aspects of the research during the consent process, including revealing the objectives and nature of the research to the participants [128, 129].

The first experiment applied the time pressure factor, followed by the difficulty adjustment in the second experiment. Then, an adaptation of patterns that randomized difficulty distribution and subgoal distribution was applied for the third experiment. Pre- and post-test experiments were set up by pre-evaluating the performance and engagement through the score and time used before gamified elements were excluded, and post-evaluation after implementing the gamified elements was included. Multiple-choice quizzes (generally four choices) were conducted on the participant's device in real-time (tablet or computer). This pre- and post-test allowed us to obtain the results of using such gamification. Such interventions caused a shift in motivation and engagement. As such, the experiment focused on changing the parameters and inputting new adaptations related to challenge-based gamification to determine its suitability, which would affect the engagement and achievement of the participants. Therefore, the experimental methods in this study were used to confirm the potential impact through gamification and to determine the fundamental optimal point of incorporating gamified elements such as a challenge.

This study provides the metrics and indices by by using the same number of questions Q, amount of time per each t, and difficulty level in three different experiments. Ten random participants ($n = 10$) were invited to be interviewed regarding their learning and perceived experiences of the gamified quizzing. Two participants were randomly assigned from five classes to discover the diverse impacts amongst the five classes and obtain various information. The interviewees had different demographics, such as age and baseline capabilities (education level of elementary students). Concerning the ethical issues of the study, a heavy disguise strategy [130, 131] was adopted since the quantitative data were collected directly from the user interactions with the quizzing platform through their dashboard and leaderboard. Additionally, any related information that could identify the participants personally in the interviews was excluded unless explicit consent was given when recounting the responses.

3.4.3 Gamified Platform: Kahoot!

Most academics agree that maintaining students' motivation, interest, and attention throughout a lecture is challenging. A lack of motivation can lead to poor learning outcomes and a hostile environment in the classroom [132]. An extensive study indicated that they developed student response systems used in classrooms for decades.

Kahoot! is a game-based learning platform that allows users to create and play quizzes, discussions, and surveys in a game-based format [1] [53]. Kahoot! was developed from the ground up to be a video game as a game-based student response system (GSRS) [133]. The gamified elements of Kahoot! include elements such as points, badges, and leaderboards, which can be used to motivate and engage users as they participate in learning activities. Other gamified elements of Kahoot! include the ability to create and customize avatars and use game-like features such as countdown timers and multiple-choice questions. These elements are designed to create a sense of competition and challenge, which can increase engagement and motivation during the learning process.

[1] https://kahoot.com/

The review of research looks into how Kahoot! influences students' learning performance when compared to other teaching methods and technologies, how it changes classroom dynamics, and how it affects students' motivation, engagement, concentration, and enjoyment. The literature investigates explicitly how Kahoot! influences learning performance, classroom dynamics, student anxiety, and student and instructor perspectives [15].

A user can upload images or videos and set the time the players have to answer each question (5 to 120 s). Each question is worth 1000 points, divided into four options with corresponding marks. Correct answers are rewarded points based on their speed; the faster the response, the higher the score [15]. The results are displayed on the screen when all participants have completed all the questions. The number of correct and incorrect responses and the lists of participants with the most points (leaderboard) was displayed on the screen [117]. As a result, the parameters examined in this gamified platform were time and difficulty level. Figure 3.3 and 3.4 show a screenshot of the platform interface and available parameters in the quiz, which educators can adjust, including the number of questions, time limit (question timer), and randomization of the answer order.

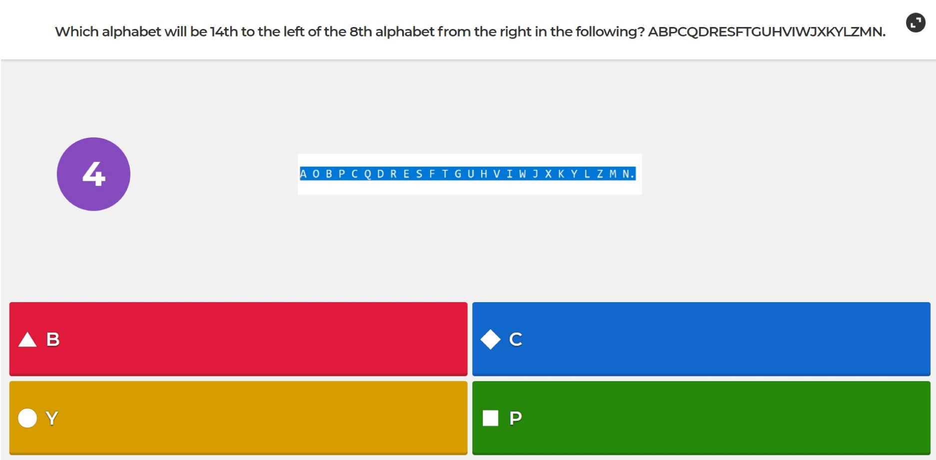


FIGURE 3.3. A screenshot of the Kahoot! user interface.

The current study used quizzes to reflect and capture student engagement and learning impact via challenge-based gamification. Student motivation in the gamified activity was demonstrated by more correct responses and time spent in the three distinct variations throughout

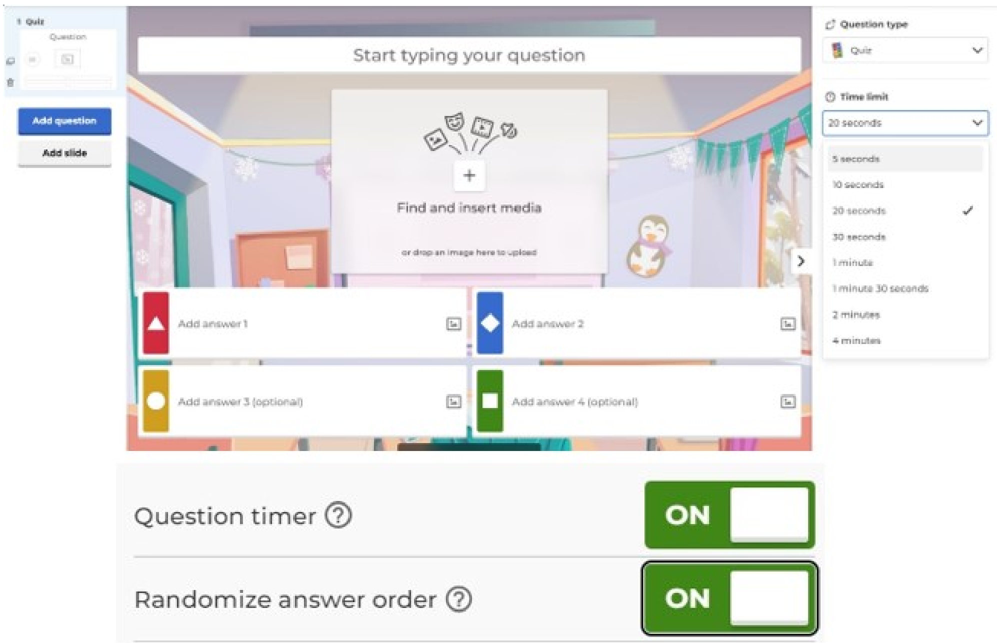


FIGURE 3.4. A screenshot of the Kahoot! question creator.

the studies. The actual outcome of our proposed strategy is determined by the changes made to each game design element.

3.4.4 Procedures

The gamified assessment platform mainly provided a multiple-choice quiz with four options per question. Using our proposed challenge-based gamification approach, we developed a one-group pretest—post-test design with two segments for pre- and post-treatment. The non-treatment group does the pre-measurement test without a timer, with basic questions and a non-gamified quiz. This pre-measurement could be compared to traditional quizzing. The experiment was repeated three times with the same group of participants to examine each time individuals' interaction and growth performance [134]. The participants then participated in all three experiments carried out in different sessions for each class. All the conditions were evaluated on the same set of students ($n = 120$) using various challenge-based gamification approaches, allowing for comparisons and capturing the effects of different game elements on student engagement and achievement. Figure 3.5 depicts the location of the experimental processes for quantitative data.

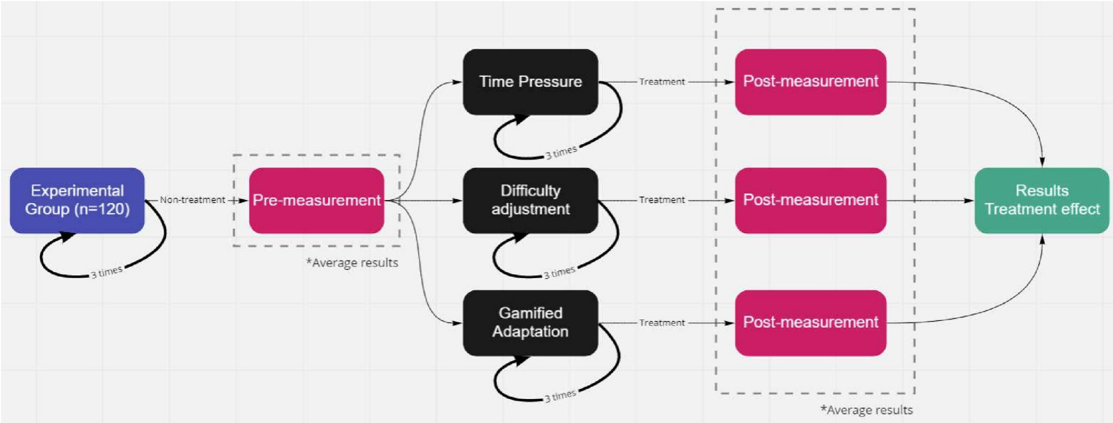


FIGURE 3.5. A one-group pretest–post-test design for the quantitative experimental study.

The first experiment started to capture the impact of engagement and motivation in the classroom, emphasizing time pressures. When considering time pressure as a challenge, a balance should be made between the degree of time pressure and participants' competence to fulfill the goal under that time pressure. The primary purpose of this study was to evaluate the effect of time pressure on player engagement and achievement in gamified quizzing. If these relationships were discovered, the next goal was to find the optimal solution between time pressures and motivation, flow, engagement, and performance (quiz completion time). A timer was used under the experimental circumstances to represent time pressure in the game.

The second experiment was conducted to investigate the impact of changing the difficulty level of quizzes, focusing on the complexity and difficulty that reflect individual skills and performance. The experiment conditions involved setting the given time for answering questions t, the total time for the whole session T scheduling, and the number of questions Q. Additionally, the set of questions was adjusted from easy to hard to investigate the impact of increasing the challenge level during quizzing. We averaged the results from all three experiments, and data were obtained based on the performance (correctness or correct answers c). However, the difficulty level was the same, but the questions varied each time to avoid rote memorization.

The third experiment addressed gamified adaptation. We changed the game mechanics to examine the potential of game elements such as randomness and subgoal achievement, which were included in this study. We adapted the game elements and traditional quizzing mechanics to alternative styles for the adaption. These two adaptations were eventually identified as the sense of progression and unpredictability. Notably, challenge-based gamification in quizzing was found to have a significant impact despite the consequences of gamification fading over time. Initially, we included these game elements for randomization because they influenced how each session appeared. The experimental conditions were established: the time given for answering questions t, the total time allotted for the session T, and the number of questions Q. Furthermore, the set of questions was altered to be simple, medium, or challenging in order to evaluate the influence of increasing the difficulty of quizzing. The three sessions' outcomes were averaged, and data were collected based on performance (correctness or correct responses c). Randomization induced unexpected events in the first adaptation, increasing the risks and challenges. This technique was essential for reflecting the simultaneous time pressure and difficulty adjustment. The difficulty level would be ideal for addressing the subgoal, depending on the participant's skills. This mechanic in the second adaptation provided feedback regarding who chose a wrong answer and increased the difficulty students experienced during the quiz. The learning principle of this game mechanic is that repetition helps with memory, and feedback helps people learn from their performance. Once the first question is answered correctly, the user is able to answer all subsequent questions correctly. The main aim of this adaptation was to understand the quiz contents in order to acquire cognitive knowledge. The scoring algorithm was not applied in this part: only whether the answer was correct was provided. This method produced a high-risk challenge throughout the session that would help stimulate engagement and learning.

3.4.5 Data Collection

In the post-measurement stage, data was gathered based on the achieved performance (correctness) and rate (time used). The impact of the gamification technique on the motion in mind parameters was observed, which can be interpreted differently from multiple prospective abilities and engagement viewpoints. The obtained score and time were computed using the proposed progress model in the assessment section. Information was extracted directly from the platform to eliminate vulnerable and marginalized gaps, and the data were synthesized and reported to participants after each session.

In this study, the control variables were held constant using the experimental protocols for all participant sessions. For instance, the instructions and time spent on an experimental task were the same for all participants during gamified quizzing, since we were constructing a method of measuring and capturing the impact through occurrences of engagement and achievement. In each experiment, the number of questions Q, the amount of time per question t, the difficulty of questions, and the questions set for all participants were established to minimize the potential interference induced by different procedures and characteristics all set via the gamified platform.

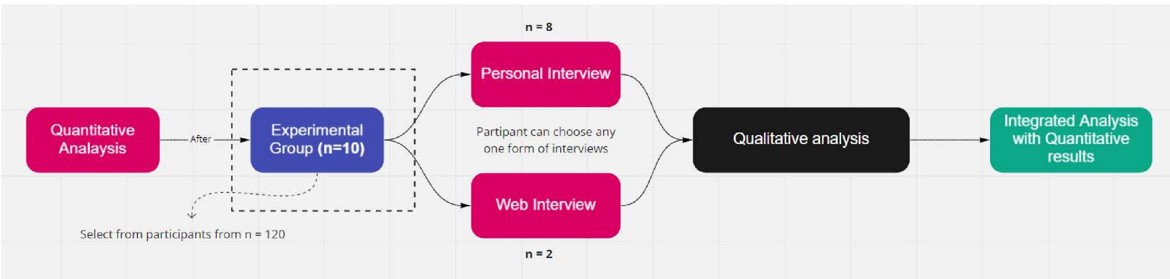


FIGURE 3.6. A flowchart for our qualitative experimental study using interviews.

Qualitative data were collected to empirically support the analytical validity from the theoretical perspective, as shown in Figure 3.6. Semi-structured interviews were used in this study to indicate the themes to be addressed and to allow the interviewer or respondent to pursue an idea or remark in further depth [125]. The gamified treatment group consisted of ten participants, with interviews scheduled for those who participated in all gamified conditions. To obtain qualitative study data, we posed six questions to each of the ten participants ($n = 10$). This flexible interview format allows participants to explore or elaborate on vital information. Qualitative interview approaches are supposed to provide a more in-depth understanding of social processes than quantitative ones. Participants were given two options: a personal interview or an online interview. Personal interviews were conducted in person for individuals who were available on a certain day. Online interviews were conducted via live-streaming video via Zoom for individuals who were unable that day. The length of the interviews varied depending on the participant, and all sessions may be conducted in either Thai or English, depending on the participants. In-person and online interviews often lasted 15-20 minutes, allowing us to gather more information and ensure that participants understood the questions. After the quantitative sections were completed, the data were analyzed by focusing on the themes of challenge-based gamification impact, experiences, and related to motion in mind theory. Suggestions or other comments were recorded if they were linked to favorable or bad outcomes, resulting in new research findings incorporating time pressure, difficulty, and gamified adaptations. We could complete this notion and bridge the gap between its commonalities and flow theory by inductively focusing on key phrases and all relevant interview scripts, including engagement and learning impact.

The questions began with what the participants experienced and acquired from the methodological experiment, which they could promptly respond to before moving on to more sophisticated or subjective themes. This can put respondents at ease, increase their confidence and familiarity, and provide rich data to aid in the interview's progression. The questions asked were open-ended, objective, sensitive, and straightforward (see Appendix 5.4). This procedure was also carried out and followed after the quantitative experiment. Respondents were informed about the study's objectives and ensured ethical principles such as anonymity and confidentiality before an interview. To guarantee that participants comprehend, various skills and approaches must be employed to obtain comprehensive and representative data throughout an interview [125]. At the end of the interview, the moderator assists participants in clarifying their ideas and asks if they have any more comments. Reflecting on participant comments and making probing observations were used to help participants to understand the process and ensure that participants were not intimidated. The participants' perceptions were permitted to influence the root questions. If the response is ambiguous, it is a good idea to ask for clarification. This usually results in the acquisition of novel and unexpected information. This is subject to ethical standards researchers must follow, such as the principles of integrity, honesty, objectivity, and transparency [128]. These questions were constructed to consider the impact after applying gamified quizzing to capture user engagement and learning impact subjectively. A theoretical discussion was employed to obtain in-depth information to obtain our findings in quantitative analysis.

Throughout this explanation, quantitative and qualitative data were merged to validate the results and draw meta-inferences, gaining additional insight or new interpretations. We assumed that challenge-based gamification could reinforce positive feedback regarding behaviors and outcomes. Data were obtained at various stages of the gamification process. As a result, different adaptations could be contrasted and explored. The analysis process is initiated after the data is collected.

3.5 The Proposed Assessment Method

3.5.1 Quantitative Measures

The quantitative data analysis was carried out using the parameters of the motion-in-mind concept and game refinement theory. This section provides essential insights regarding this study's overall model. The level of engagement was measured using the motion-in-mind concept, which needed interpretations from several values to validate the context to be addressed. We evaluated the qualitative analysis and the behavioral changes identified to fill this gap and clarify the learning impact. This measurement provided objectivity and subjectivity, from which reliability and validity could be identified in quantitative and qualitative data. Including the interviews, the qualitative findings inductively support the quantitative data, providing additional insights from different viewpoints. The formulation and numerical assessment of the theory are explained below based on the two indices.

3.5.1.1 Time Used

In the first experiment, we collected the time required for the whole session, and determined the average for each quiz. We varied both the time allowed for each question t and the number of questions Q in each quiz. The experiment was separated into 5 different numbers of questions; $N = 5, 10, 15, 20,$ or 30. Likewise, given the time allowed, each question was divided into 5 different times: $t = 5, 10, 20, 30,$ or 60 s. Time pressure can be considered as the progression of game refinement theory. Typically, the solving rate v is defined by using the average amount of time used to answer the questions (AT), and the game length is the total amount of time required to complete the whole quiz (T), with $v_1 = \frac{AT}{T}$ referring to (3.1). The game progress model is established from derivation in Section 3.1, which is defined as (3.2), Thus, we obtained $a_1 = \frac{2v}{T} = \frac{2 \cdot AT}{T^2}$ referring to Equation (2.9).

$$v_1 = \frac{average\ amount\ of\ answer\ time\ used}{total\ amount\ of\ time\ of\ whole\ quiz} \tag{3.1}$$

$$a_1 = \frac{2 \cdot average\ amount\ of\ answer\ time\ used}{(total\ amount\ of\ time\ of\ whole\ quiz)^2} \tag{3.2}$$

3.5.1.2 Quiz Scores (Correctness)

Both the second and third experiments focused on the correctness perspective. Varying times allowed for each question t, and the numbers of questions Q were incorporated with differences in difficulties and patterns. The second experiment was separated into three question numbers ($N = 5, 10$, or 20) and each question was divided into three different times ($t = 5, 10$, or 20 s). The difficulty was categorized into easy, medium, or hard[2]. The quizzing solving rate was the same as the game progress model's scoring rate, assuming that the quiz score was equal to one correct answer. Therefore, solving rate v_1 is defined by using the average numbers of correct answers c and the total numbers of questions Q as defined in (3.3). The objective acceleration a_1 is defined as (3.4), where $a_1 = \frac{2 \cdot AT}{T^2}$, as defined in (2.9).

$$v_1 = \frac{average\ numbers\ of\ correct\ answers}{total\ numbers\ of\ questions} \tag{3.3}$$

$$a_1 = \frac{2 \cdot average\ numbers\ of\ correct\ answers}{(total\ numbers\ of\ questions)^2} \tag{3.4}$$

Similarly, the third experiment was conducted to examine the impact of various patterns that adjusted the difficulty level. The third experiment was separated into three question numbers ($N = 10, 20, or$ 40), and each was allowed one of three different times ($t = 5, 10$, or 20 s).

[2] https://hitbullseye.com/puzzle/easy-logic-puzzles.php

The game progress model was the same as in (3.2) but with a specific difficulty that required problem-solving skills.

3.5.2 Qualitative Measures

This study aimed to comprehend and investigate the impact and perception of participants' subjective experiences throughout a challenge-based gamification activity by using interview questions from items 1-4 in Appendix 5.4). Items 5 and 6 enlarged the interview in order to capture participants' responses to and overall motivation for challenge-based gamification. Furthermore, the generality of the item (e.g., what do you think) minimized biases by allowing the participant to discuss particular and additional features early in the interview. A prior study specified which game features were investigated and executed, what educational levels were used, and the evaluation results [135]. Unfortunately, no investigation of the overall impact of gamification on student progress was undertaken in that study.

Because they operate as enablers in the classroom, educators play a prominent role in practicing and identifying gamification. Palmquist conducted a semi-structured interview with stakeholders, followed by thematic analysis [136]. In another study by Bai et al., thematic analysis was used to incorporate meta-analysis evidence from qualitative studies to get insight into individuals' academic performance with gamification intervention [137].

Thematic analyses were also conducted to extract more personalized information, such as participants' experiences, views, and opinions in this study. Another study by Braun and Clarke followed the six phases of thematic analysis, where the data were derived from interviews and conversations Braun and Clarke [138]. The thematic analysis involves identifying the meaning behind patterns by evaluating the themes within the dataset. As thematic analysis tends to be exploratory and driven by the research questions, it can be developed into a coding phase and theme identification.

In this study, the adopted coding was a mixture of inductive and deductive approaches that reflect students' experiences. A data-driven inductive approach defines emergent themes, which assist in deriving meaning and creating themes from data without any preconceptions.

The deductive approach formulates the categorization by jumping into the analysis with themes related to the research questions. Typically, this approach is informed by prior knowledge and is uncommon in HCI research [139]. This method supports the relationships within the data and provides the flexibility to identify emerging categories from the data. Therefore, semistructured interviews were adopted, which provided a balance between the two approaches and is one of the most commonly adopted qualitative approaches in HCI research [139].

All qualitative data collected were analyzed separately in the data analyzing tool MAXQDA[3]. All transcripts were reviewed by focusing on exploring conceptual relations and forming patterns [138]. The clusters and connections of the initial patterns were distinguished during the initial coding. Subsequently, a thematic map was created for clustering the patterns for matching themes, subthemes, and codes. Finally, the results were adopted from methodological and theoretical triangulation, integrating qualitative to quantitative data and interpreting qualitative outcomes through various theoretical perspectives.

3.6 Quantitative Results

This study aimed to capture the impact of variation in challenge-based gamification using the gamified platform Kahoot! To achieve this, we used the scoring rate and time to determine and evaluate individuals' performance. The proposed formulation calculated these data in order to determine the outcomes and interpretations based on the motion in mind. According to Section 3, the motion-in-mind concept suggests finding motions in an object and describing such formulations using velocity, force, mass, and energy. This would describe the mechanism of challenge-based gamification in any task, including educational activities. To bridge the gap between physics and psychology, we investigated the optimal level of gamification in the activity. We stated the position of individual motion using both ideas of motion in mind and flow theory. The validity and reliability of this experiment were determined using a mixed method. As a significant aspect of the study, we conducted a quantitative analysis

[3] https://www.maxqda.com/

initially, followed by a qualitative analysis to obtain additional insights. For our quantitative analysis, we conducted three experiments to observe and determine the effects of changes in the parameters based on motion in mind. Velocity v and mass m are essential indicators to discover the pattern of challenge-based gamification and other meanings with physics value, including force F and potential energy E_p. Additionally, we interviewed participants to obtain qualitative data, which supports the quantitative data in the broader aspects of psychology, such as flow theory and the theory of gamified learning.

According to [140], the typology of engagement in this gamified context was identified and elaborated in a gamification intervention. Two types of engagement were reported as learning engagement in this study. Consequently, we attempted to investigate occurrences of cognitive and behavioral engagement via quiz scores and time used. The first three sets of analyses capture the impact of challenge-based gamification by using quantitative analysis. The results obtained from the preliminary analysis of pre-measurement and post-measurement with no control group data are summarized in Table 3.2. It is apparent from this table that a timer can encourage students to focus on the task since the time remaining to complete the task was decreasing. However, the score c was inverted so that the students received a higher score for completing the task more quickly under the condition of the number of questions $Q = 10$ and time for each question $t = 10$. This condition resulted in attaining higher learning gains compared to the non-gamified condition.

TABLE 3.2. The pre- and post-test treatment effect of challenge-based gamification experiments.

Pretest	$Tot.Ave.$	c	**Post-test**	$Tot.Ave.$	c
No-timer	92.5	6.3	Timer	64	7.5
Easy level	60	6.3	Increased level of quiz	76	5.93
Non-gamified adaptation	88	3.83	Difficulty randomness	62	7.42
			Sub-goal	72	4.25

Tot. Ave., total average time required; c, average number of correct answers.
$N = 10$ and $t = 10$

Difficulty changes increased the time required to complete the session and decreased the scores. This increased the difficulty of the challenge-based gamification to higher than the students' skills. This situation reflects that students were cognitively disengaged when the challenge level was too high. The different difficulty levels were used to guide learners in setting achievable goals and developing competencies in a stepwise fashion. In this sense, dynamic adaptation could be helpful for further analysis. In the gamified adaptation, the score improved, and the time used decreased. This finding implies that game characteristics influence changes in behavior [17]. Specifically, the considered gamified experience significantly encouraged both behavioral and cognitive engagement.

To understand this gamified experience in-depth, we answered the first and second research questions using quantitative analysis. The findings were divided according to the different types of experiments. The analyzed data were computed considering the motion-in-mind concept.

3.6.1 Analysis of Time Pressure

The experiment was conducted three times for several questions where the time used was recorded. Then, the average time for each session and each preference was computed. Determining GR involves the time required to answer each question, while the total number of questions corresponds to the session's length of time. We observed that the number of questions affected the total time, which explains the decrease in GR. Table 3.3 shows the measures of the game refinement value GR and risk chance m, based on (3.1) and (3.2), respectively.

According to game refinement theory, a sophisticated zone always implies a balance between skill and chance. Most popular games are located in the sophistication zone in the GR measure ($GR \in [0.07, 0.08]$), which implies the magnitude of the thrilling sense. Figure 3.7 depicts the risk chance of m and the GR value against the time allowed for each question based on the total number of questions. This gamified platform was achieved with a total question number Q of 5, 10, 15, 20 and 30, and a time allowed for each question t of 60, 30, 20, 10, and 5, respectively. Figure 3.7(a) and 3.7(b) showed that when the total number of questions was above 15, the time required for each question, which satisfies the sophistication zone, was about 7-9 seconds and less than 5 seconds, respectively. The risk chance m tended

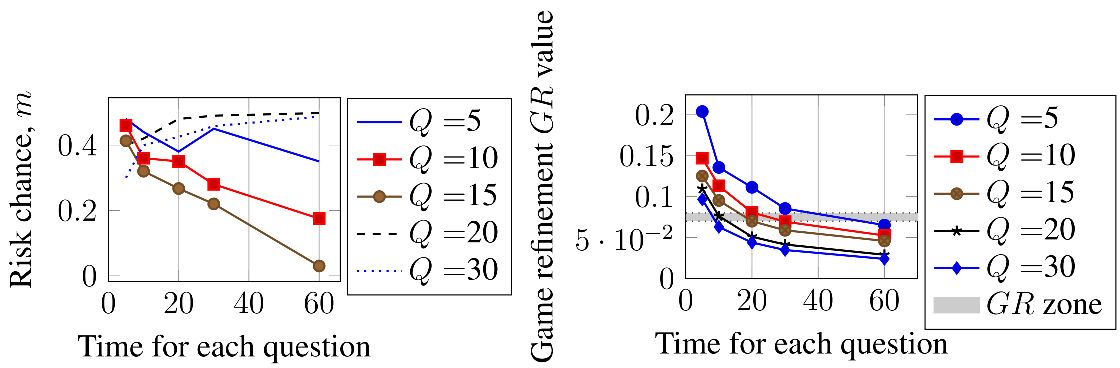
TABLE 3.3. Measures of game refinement GR and risk m of Kahoot! with different numbers of questions and question answering times.

Total Questions (Q)	**Question Time (s)** Each	Total	Tot. Ave.	$m = 1 - v$	GR
5	5	25	13	0.480	0.2039
	10	50	23	0.440	0.1356
	20	100	62	0.380	0.1113
	30	150	82	0.450	0.0854
	60	300	191	0.350	0.0651
10	5	50	27	0.460	0.1470
	10	100	64	0.360	0.1131
	20	200	130	0.350	0.0806
	30	300	216	0.280	0.0693
	60	600	495	0.175	0.0524
15	5	75	44	0.413	0.1251
	10	150	102	0.320	0.0952
	20	300	220	0.267	0.0699
	30	450	350	0.220	0.0588
	60	900	850	0.030	0.0458
20	5	100	60	0.400	0.1095
	10	200	116	0.420	0.0761
	20	400	208	0.480	0.0509
	30	600	308	0.490	0.0414
	60	1200	602	0.498	0.0289
30	5	150	105	0.300	0.0966
	10	300	178	0.400	0.0629
	20	600	345	0.425	0.0438
	30	900	488	0.458	0.0347
	60	1800	922	0.487	0.0238

Tot. Ave., total average of time;
$m = 1 - v$, risk ratio; GR, game refinement measure.

to increase when $N = 20$ and $N = 30$ because more time was used to answer the question based on the variation in the question time and individuals' skills. Because of the additional time, the individual was more likely to doubt their ability to respond to and answer the question incorrectly. Interestingly, the total time T (quiz length), which satisfies GR, was situated around 150-300 seconds. Following the relationship of Q and t, the results revealed that time pressure affected the students' engagement. As the number of questions increases, the time used on each question should be reasonable to allow the individual to assess and focus on the experience as much as possible.

Motion-in-mind concept further describes the results in a systematic and detailed way. Closer inspection of the Table 3.4 provides the data analyzed via motion in mind in terms of momentum ($\vec{p}$) and potential energy (E_p). The maximum plateau of $\vec{p}$ was achieved when $m = \frac{1}{2}$, so that $\vec{p} \leq \frac{1}{4}$. This gamified platform was optimal $\vec{p}$ when the total question number



(a) Risk chance m versus the time for answering the question

(b) Game refinement GR measure versus the time for answering the question.

FIGURE 3.7. A visualization based on different total question numbers.

and time taken for each question were both low (or high) simultaneously. From this data, we can see that individuals could pay more attention in short sessions or long sessions because students were convinced to handle the game, and over time, they identified the competitive aspects. Individuals might have felt that the intensity was reasonable because of the perceived fairness. Increasing of Q and t provides fairness experience to individuals since there is a space to evaluate themselves with reasonable length. However, the results highlight the same fashion, in which the balance between Q and t is required to optimize mass m.

Another aspect, E_p showed that students obtained motivation from the game. From this result, we found that a total number of questions Q of 5 or 10 was the best choice to motivate students during this gamified activity. Gamification's positive effect can produce extrinsic motivation in the user in the early stage of the game. Therefore, gamification worked when the total time allowed for the whole session was around 100-150 seconds. When the risk-taking chance m was higher, students may have felt discomfort and lost the desire to continue the game since the task's resistance was greater.

According to game's acceleration mentioned in Equation (2.9), gamification can be described by game refinement measure, and this is enseential to achieve force in the context of education. The law of conservation of energy is obtained from $E_p = \vec{p_1} + \vec{p_2}$, where $\vec{p_1}$ and $\vec{p_2}$ are the objective momentum and subjective momentum, respectively. Subjective acceleration a_2 is derived from $\vec{p_2} = mv_2$, which indicates the subjective aspect of risk-taking chance m,

TABLE 3.4. Measures of momentum $\vec{p}$, potential energy E_p, and risk m with different numbers of questions and time allowed to answer the questions

Total Questions (Q)	**Question Time (s)** Each	**Question Time (s)** Tot. Ave.	m	$\vec{p}$	E_p
5	5	13	0.480	0.2490	0.2595
	10	23	0.440	0.2484	0.2285
	20	62	0.380	0.2356	0.2921
	30	82	0.450	0.2478	0.2709
	60	191	0.350	0.2313	0.2945
10	5	27	0.460	0.2484	0.2682
	10	64	0.360	0.2304	0.2949
	20	130	0.350	0.2275	0.2957
	30	216	0.280	0.2016	0.2903
	60	495	0.175	0.1443	0.2382
15	5	44	0.413	0.2424	0.2845
	10	102	0.320	0.2176	0.2959
	20	220	0.267	0.1955	0.2868
	30	350	0.220	0.1728	0.2688
	60	850	0.030	0.0524	0.0991
20	5	60	0.400	0.24	0.2880
	10	116	0.420	0.2436	0.2825
	20	208	0.480	0.2496	0.2595
	30	308	0.490	0.2498	0.2564
	60	602	0.498	0.2499	0.2508
30	5	105	0.300	0.21	0.2940
	10	178	0.400	0.2412	0.2863
	20	345	0.425	0.2443	0.2810
	30	488	0.458	0.2482	0.2691
	60	922	0.487	0.2497	0.2559

Tot. Ave.: total average of time;
$m = 1 - v$, risk ratio; $\overrightarrow{p}$, momentum; E_p, potential energy.

and subjective velocity is defined as $v_2 = 2m^2 - 3m + 1$. Both measures represent the quantification of player's enforcement in the game; players execute effort to drive the game forward. Objective parameters were considered as the game's ability to build a thrilling experience and create satisfaction.

Table 3.5 shows that subjective acceleration a_2 and force F_2 were negative in every possible setting. Intuitively, a positive force for F_1 corresponds to individuals' challenge experienced when playing the game; however, force F_2 corresponds to a negative acceleration change over risk-taking chance. Games with a small m retained negative force F_2, with a negative peak value at $m = \frac{3}{8}$ where $F_2 = -0.5625$. This supports the conjecture that low (negative) F_2 and high (near peak/peak) E_p indicate the lowest learning resistance (game's inertia is high) and motivation (high information expectant/availability). The results demonstrate that time pressure can foster engagement and motivation when individuals are captivated by the game.

Notably, a larger m seemingly created a greater force, signifying that the intrinsic motivation, even discomfort, dominated this situation.

TABLE 3.5. Measures of subjective acceleration a_2, subjective force F_2, and risk m with different numbers of questions and question times

Total Questions (Q)	**Question Time (s)**		m	a_2	F_2
	Each	**Tot. Ave.**			
5	5	13	0.480	-1.08	-0.5184
	10	23	0.440	-0.84	-0.4636
	20	62	0.380	-1.48	-0.5624
	30	82	0.450	-1.18	-0.5379
	60	191	0.350	-1.55	-0.5619
10	5	27	0.460	-1.16	-0.5336
	10	64	0.360	-1.56	-0.5616
	20	130	0.350	-1.6	-0.56
	30	216	0.280	-1.88	-0.5264
	60	495	0.175	-2.3	-0.4025
15	5	44	0.413	-1.346	-0.5566
	10	102	0.320	-1.72	-0.5504
	20	220	0.267	-1.93	-0.5155
	30	350	0.220	-2.11	-0.4691
	60	850	0.030	-2.77	-0.1543
20	5	60	0.400	-1.4	-0.56
	10	116	0.420	-1.32	-0.5544
	20	208	0.480	-1.08	-0.5184
	30	308	0.490	-1.05	-0.5126
	60	602	0.498	-1.01	-0.5016
30	5	105	0.300	-1.8	-0.54
	10	178	0.400	-1.37	-0.5585
	20	345	0.425	-1.3	-0.5525
	30	488	0.458	-1.17	-0.5351
	60	922	0.487	-1.05	-0.5116

Tot. Ave.: total average of time;
$m = 1 - v$, risk ratio; a_2, subjective acceleration = $4m - 3$,
F_2, subjective force = ma_2.

3.6.2 Analysis of Difficulty

The various difficulty levels may provoke different aspects of fairness, engagement, and motivation [67, 68]. This experiment was conducted to observe the effects of alterations in the quiz difficulty to analyze the nature of m based on correctness (i.e., how students can obtain information from quizzing). The target quizzes were characterized into three levels;

easy, medium, and hard, and distributed in each session. We found that m values increased when difficulty was higher since players could not correctly answer the quiz. The difficulty was judged using m value in terms of risk frequency ratio, which was used to determined the correctness rate over the total number of questions according to (3.3) and (3.4). When applying a challenge that can quickly increase the risk-taking chance, a gamified experience would be obtained if and only if $m \geq \frac{1}{2}$.

TABLE 3.6. Measures of risk chance m, objective momentum p_1, potential energy E_p, and subjective momentum p_2 based on variations in the number of questions number and time required for every quiz difficulty level

Q	t	T	**difficulty:easy**					**difficulty:medium**					**difficulty:hard**				
			c	m	$\vec{p_1}$	E_p	$\vec{p_2}$	c	m	$\vec{p_1}$	E_p	$\vec{p_2}$	c	m	$\vec{p_1}$	E_p	$\vec{p_2}$
5	5	25	3.93	0.214	0.1682	0.2644	0.0962	3.3	0.34	0.2244	0.2962	0.0718	2.21	0.558	0.2466	0.218	-0.0286
	10	50	4.66	0.068	0.0634	0.1181	0.0548	3.67	0.266	0.1952	0.2866	0.0914	2.48	0.504	0.2499	0.24798	-0.0019
	20	100	4.83	0.034	0.0328	0.0635	0.0306	4.22	0.156	0.1316	0.2222	0.09058	2.57	0.486	0.2498	0.2568	0.0069
10	5	50	6.9	0.31	0.2139	0.2952	0.0813	5.12	0.488	0.2499	0.2559	0.0059	3.4	0.66	0.2244	0.1526	-0.0718
	10	100	7.5	0.25	0.1875	0.2813	0.0938	5.93	0.407	0.2414	0.286	0.0449	3.93	0.607	0.239	0.188	-0.0511
	20	200	7.93	0.207	0.164	0.2603	0.096	6.1	0.39	0.2379	0.2902	0.0523	4.33	0.567	0.2455	0.2126	-0.0329
20	5	100	8.4	0.58	0.2436	0.2046	-0.0389	6.45	0.678	0.2185	0.1409	-0.0776	5.3	0.735	0.1948	0.1032	-0.0915
	10	200	11.35	0.433	0.245	0.2785	0.0331	6.88	0.656	0.2256	0.1553	-0.0704	5.33	0.734	0.1955	0.1042	-0.0913
	20	400	14	0.3	0.21	0.294	0.084	7.24	0.638	0.231	0.167	-0.0637	5.75	0.7125	0.2048	0.1178	-0.0871

Q, total questions; c, average numbers of correct answers; m = 1-v, risk ratio;
E_p = $\vec{p_1} + \vec{p_2}$; $\vec{p_1}$, objective momentum; $\vec{p_2}$, subjective momentum.

Table 3.6 displays the values of m, $\vec{p_1}$, E_p, and $\vec{p_2}$ for every quiz difficulty level. The results show that most configurations were located in varied risk chance m; this formulation reflects the reduction in risk chance m based on the total number of questions Q and time taken t. This finding implies that increasing the difficulty of the quiz increased the risk chance; gamified activity was more engaging and risky at the same time. Individuals become competitive ($m > 0.5$), and devote more effort to the quiz, or stay in the comfort zone ($m \leq 0.5$).

There is a significant result in each motion-in-mind measure. This experiment listed motion-in-mind parameters of $\vec{p_1}$ and E_p and highlighted the significant data as below:

- $\vec{p_1}$ indicates the magnitude of engagement in the quiz, which peaked at pair $(N, t) = (20, 10)$ for the easy quiz, $(N, t) = (10, 5)$ for the medium difficulty, and $(N, t) = (5, 10)$ for the hard quiz.

- E_p describes the potential of a quiz's movement; peak values were obtained at pair $(N, t) = (10, 5)$ in the easy level, $(N, t) = (5, 5)$ in the medium level, and $(N, t) = (5, 20)$ in the hard level.

These results are associated with quiz engagement when the challenge was introduced, and quiz curiosity was noted when students felt under control with the appropriate amount of challenge. Highly engaged learners were involved in an arousal situation when $m \leq 0.5$, where difficulty reduced curiosity (information expected from learners), while the time and the number of questions stabilized with experience to contribute to overall activity outcome efficiency.

TABLE 3.7. Measures of risk chance m, subjective acceleration a_2, and subjective force F_2 based on variations in the number of questions and the time for every level of quiz difficulty

Q	t	T	**difficulty:easy**				**difficulty:medium**				**difficulty:hard**			
			c	m	a_2	F_2	c	m	a_2	F_2	c	m	a_2	F_2
5	5	25	3.93	0.214	-2.14	-0.459	3.3	0.34	-1.64	-0.558	2.21	0.558	-0.768	-0.429
	10	50	4.66	0.068	-2.73	-0.186	3.67	0.266	-1.94	-0.515	2.48	0.504	-0.984	-0.496
	20	100	4.83	0.034	-2.86	-0.097	4.22	0.156	-2.38	-0.370	2.57	0.486	-1.056	-0.513
10	5	50	6.9	0.31	-1.76	-0.546	5.12	0.488	-1.05	-0.511	3.4	0.66	-0.36	-0.238
	10	100	7.5	0.25	-2	-0.5	5.93	0.407	-1.37	-0.558	3.93	0.607	-0.572	-0.347
	20	200	7.93	0.207	-2.17	-0.449	6.1	0.39	-1.44	-0.562	4.33	0.567	-0.732	-0.415
20	5	100	8.4	0.58	-0.68	-0.394	6.45	0.678	-0.29	-0.196	5.3	0.735	-0.06	-0.044
	10	200	11.35	0.433	-1.27	-0.549	6.88	0.656	-0.38	-0.247	5.33	0.734	-0.066	-0.048
	20	400	14	0.3	-1.8	-0.54	7.24	0.638	-0.45	-0.286	5.75	0.7125	-0.15	-0.107

Q, total questions; c, average numbers of correct answers; $m = 1 - v$, risk ratio;
a_2, subjective acceleration = $4m - 3$; F_2, subjective force = ma_2.

For deeper details, Table 3.7 highlights the other two parameters, subjective acceleration a_2 and subjective force F_2, for interpreting the context of learning and engagement. a_1 defines the rate of game information over time, so this acceleration will foster a thrilling experience for players. As such, individuals are pushed to play if playing is perceived as accelerating the solving rate. Simultaneously, a large amount of a_2 can reduce the individual's effort based on risk chance, this defines a thrilling experience for individuals perceived from the activity. Naturally, students solve an easy game with high effort instead of high risk. Adding challenge-based gamification stimulates a student's cognitive curiosity. Therefore, a negative value of force F_2 can be defined as the game's inertial force; in a sense, a negative value is meant to be a force pushing the user to play the game. A negative peak of F_2 was obtained at

$m = \frac{3}{8}$ with $F_2 = -0.5625$; thus, entry difficulty at various levels affects the change around this negative peak. The least resistance force F_2 was mostly obtained at the easy and medium levels in this experiment. F_2 decreased as players went through the game with less challenge adjustment, and the student anticipated continuing the game. Hence, the data shows that easy and medium levels provide the risk chance around $m = \frac{3}{8}$, especially when $N = 10$ and 20 for the easy quiz and $N = 5$ and 10 for the medium quiz. Time pressure can affect the risk chance m, this influenced the student's performance because they had to struggle to complete the task. Based on the game progress model, the challenging level seemed to escalate the player's resistance when $m \geq \frac{1}{2}$, denoting a tense situation.

3.6.3 Analysis of Pattern Adaptation

This experiment was hypothesized that random distribution will improve thrill experiences and challenging experience since it will generate uncertainty during the game. Such a situation is related to the player going out of their comfort zone but still being conservative as the player is encouraged to be in the arousal state. It will maintain the engagement to keep learning or playing. This experiment intends to observe the impact similar to the time pressure and difficulty, affecting engagement and challenging experience.

The use of randomized difficulty patterns and subgoal patterns resulted in various learning processes and outcomes in both learning and enjoyment. Uniform random distribution was applied for the randomized pattern where each question had the same selection chance. This methodology hypothesizes that random distribution improves thrill and creates a challenging experience since it generates uncertainty during the game. This situation describes players leaving their comfort zone but still being conservative as they are encouraged to be in the arousal state; thus, the engagement to keep playing (or learning) is maintained due to players behaving differently. the experimental results show that players developed their skills and started from the anxiety point to the arousal zone, where the optimal condition is to acquire more skills and information.

The experimental findings of this adaptation are illustrated Tables 3.8 and 3.9, in which the average number of correct answers c is used to represent various motion in mind metrics. The m for each value was modified, correlating to the time (t) and total number of questions (Q) for each question. The experimental results emphasize the predominant risk ratio, where high uncertainty with time pressure for each question was decisive. Additionally, high uncertainty occurred when a higher skill level was expected in the game. Hence, the sense of engagement and curiosity were uniform based on the motion in mind concept if the appropriate time was established.

TABLE 3.8. Measures of the physics value of motion in mind and risk m for varying numbers of questions and question time with a randomized difficulty distribution

Total Questions (Q)	**Question Time (s) Each**	c	m	$\vec{p_1}$	E_p	$\vec{p_2}$	a_2	F_2
10	5	6.33	0.367	0.2323	0.2941	0.0618	-1.532	-0.5622
	10	7.42	0.258	0.1914	0.2841	0.0926	-1.968	-0.5077
	20	7.45	0.255	0.1899	0.2831	0.0931	-1.98	-0.5049
20	5	7.36	0.632	0.2326	0.1712	-0.0614	-0.472	-0.2983
	10	8.27	0.5865	0.2425	0.2005	-0.042	-0.654	-0.3835
	20	8.89	0.5555	0.2469	0.2195	-0.0274	-0.778	-0.4322
40	5	12.3	0.6925	0.2129	0.1310	-0.0819	-0.23	-0.1593
	10	17.85	0.5537	0.2471	0.2205	-0.0265	-0.785	-0.4347
	20	21.33	0.4667	0.2489	0.2654	-0.0165	-1.133	-0.5288

Q, total questions; c, average numbers of correct answers; $m = 1 - v$, risk ratio;
E_p = $\vec{p_1} + \vec{p_2}$; $\vec{p_1} = mv$, objective momentum; $\vec{p_2}$, subjective momentum;
a_2, subjective acceleration = $4m - 3$;
F_2, subjective force = ma_2.

According to Table 3.8, randomization can create uncertainty and increase the risk ratio m, More questions Q and less time allowed t created both feelings of uncertainty and difficulty. Individuals can acquire skills to deal with such a situation, but they can feel discomfort because of the time pressure. Thus, time pressure and uncertainty influenced students in terms of difficulty, whereas time pressure caused discomfort. Intuitively, the negative peak point of F_2 implies that players were attracted and motivated to continue their activity since this point is recognized as the least resistant to learning. When the number of questions $N \geq 20$ with time pressure, a_2 converged toward a positive value, where individuals were pushed away from the activity (less attracted by the game due to high risk m).

TABLE 3.9. Measures of the physics value of motion in mind and risk m with variations in the number of questions and question time for the subgoal pattern

Total Questions (Q)	**Question Time (s) Each**	c	m	$\vec{p_1}$	E_p	$\vec{p_2}$	a_2	F_2
10	5	2.83	0.717	0.2029	0.1148	-0.088	-0.132	-0.0946
	10	4.25	0.575	0.2443	0.2077	-0.0366	-0.7	-0.4025
	20	4.67	0.533	0.2489	0.2325	-0.0164	-0.868	-0.4626
20	5	7.5	0.625	0.2344	0.1758	-0.0586	-0.5	-0.3125
	10	7.83	0.6085	0.2382	0.1865	-0.0517	-0.566	-0.3444
	20	8.23	0.59	0.2419	0.1983	-0.0435	-0.64	-0.3776
40	5	10.45	0.7388	0.193	0.1008	-0.0921	-0.045	-0.0332
	10	11.2	0.72	0.2016	0.1129	-0.0887	-0.12	-0.0864
	20	13.78	0.6555	0.2258	0.1556	-0.0702	-0.378	-0.2478

Q, total questions; c, average numbers of correct answers; $m = 1 - v$, risk ratio;
E_p = $\vec{p_1} + \vec{p_2}$; $\vec{p_1} = mv$, objective momentum; $\vec{p_2}$, subjective momentum;
a_2, subjective acceleration = $4m - 3$;
F_2, subjective force = ma_2.

According to Table 3.9, this experiment adopted the gamified adaption in order to create a clear goal to drive a meaningful activity, including immediate feedback [14]. Time, levels, and points were combined in this condition, but the mechanics of this experiment involved forcing the participants correctly answer each question to acquire the right information for the next question. The results indicate that individuals had an effort at risk ratio of $m \geq 0.5$. The feeling of discomfort was high when placing their efforts since they were aroused by uncertainty and risk in decision-making, as shown in the value of a_2. The data transitioned individuals toward performing necessary tasks (high E_p). This pattern lies in the zone of $m \geq 0.5$ where uncertainty and risk are situated, and engagement is expected to be maintained. Most games lie in this zone, indicating that the gamified experience is achieved and low skill is required. Engagement increases as learning growth decreases based on the momentum value of both the objective and subjective factors ($\vec{p_1}$ and $\vec{p_2}$).

3.7 Qualitative Results

This study found justification for applying challenge-based gamification to additionally capture its potential impact from the 10 interviewees. The qualitative results revealed two main themes concerning impacts and perceptions through the intervention of challenge-based gamification in a learning platform. Table 3.10 displays the counts of the time participants mentioned codes in the interview transcripts and themes. Examples of quotes and recorded scripts from anonymous interviewees are shown in the coding frame (see Table 3.11).

TABLE 3.10. Number of mentions by participants of codes relating to this research's themes

Themes	**Number of mentions (across all interviews)**	**Number of participant mentions (from $n = 10$)**
Impacts of Challenge-Based gamification	24	15
Perceptions of Challenge-Based gamification	10	7

TABLE 3.11. Thematic table showing themes, subthemes, and codes obtained from interview transcriptions

Themes	**Subthemes**	**Codes**	**Example Quote**
Impact of Challenge-based Gamification	Engagement Impact	Get aroused	*"I felt aroused, but I had to make an effort."*
		Competitive	*"I felt competitive, I was encouraged to complete all quizzes."*
		Anxiety	*"I could not solve the quiz in the first few questions."*
		Curiosity	*"I encountered uncertainty, but this affected my curiosity because of the unknown."*
		Surprised	*"Randomization is new to me I felt surprised in the sense of fun even though I was able to answer correctly."*
		Enjoy	*"The gamified activities were fun, and I experienced feelings of curiosity and interest."*
		Challenging	*"I was very engaged because of time pressure; it was more challenging and required focus."*
	Learning Impact	Encouragement/Reinforcment	*"The harder level drove my motivation to solve the questions. I could easily answer some of the quizzes and was bored. Then, I would prefer some more challenging tasks so I could be learning more than with easier questions."*
		Development/Learning improvement	*"I could handle the quizzes better than before, especially with time pressure. I obtained higher and better results in the end."*
		Concentration	*"I had to pay more attention and focus on the question because of timer."*
		Creativity	*"After getting used to it, I had to start guessing and considering other options."*
		Feel competence/Self-assessment	*"Gamified quizzing provided me the opportunities to realize the background knowledge."*
Perceptions of Challenge-based Gamificaiton	Behavioral changes	Motivation behaviors	*"It required concentration and motivation to complete the quiz."*
		Sustaining behaviors	*"Winning was not a target when I tried this gamified adaptation. Depending on my ability, I just wanted to go as far as possible."*
	Intervention efficacy	Allowing learning opportunities	*"When the quiz was not too difficult, I could focus more, which pushed me forward to face the challenge as a new challenge and a new learning opportunity."*
		Diversity/Variety	*"It was exciting and allowed different students to receive information differently."*
	Balancing challenges	Lack of competence	*"I had little enthusiasm when my abilities were not suited to the quizzing challenges."*
		Presence of competence	*"I solved the question that I did not know by myself; I enjoyed meeting the next level of challenges."*

This study conducted a qualitative analysis in order to understand the additional insight from the participant's viewpoints. Thematic analysis was used to analyze the theme of challenge-based gamification and measured the extent to which impacts and perceptions.

As seen from the table (above), the interview was conducted, and the exciting aspects were captured among the participants. This study is quite revealing in several ways, which, by far, the most significant impact and perceptions are for engagement and motivation. The qualitative analysis aimed to understand better gamification's impact on students' experiences and motivations. Luiz et al. investigated a multidimensional strategy for individualized gamification using thematic analysis to capture and hypothesize user motivation compared to traditional gamification implementation [141]. Dicheva et al. also conducted a thematic analysis of relevant studies on the use of gamification in the educational context [135]. These studies support our quantitative results and theoretical analysis. These results have a significant positive correlation with learning-related outcomes. The study is currently focused on two main aspects, which will be reported in a qualitative manner: *Impact* and Perceptions of challenge-based gamification.

3.7.1 Thematic Analysis on Impact of Challenge-Based Gamification

Various perspectives were expressed through the impact of challenge-based gamification, which can reflect engagement depending on many factors. One participant declared that they felt excited, but it enabled them to commit extra effort, which particularly benefited them in terms of increased engagement. This view was echoed by another informant who perceived competitiveness because he was encouraged to complete all questions in the given time. These are considered excitement and competitiveness, respectively. A little challenge may prompt people in new directions, and surprise and uncertainty with unexpected rewards could keep them engaged. A few participants provided the reason that uncertainty might increase curiosity since not everything had to be fully explained. One participant commented: "randomization is new to me; it makes me feel surprised but in a fun way because I could answer correctly." This view surfaced mainly in relation to another participant who mentioned that they had more fun and experienced feelings of curiosity and interest. The majority of participants agreed with the statement that challenge-based gamification impacts engagement, both in terms of surprise and curiosity. A common view was expressed that student engagement may be perceived as emotional engagement and subsequently enhanced by curiosity and enjoyment. Most students claimed they perceived that they were more engaged in gamified quizzing and experienced the feeling of being challenged. One mentioned that they felt engaged during time pressure quiz because it was more challenging so they concentrated more than during the quizzes without the extra conditions. This reflects the impact of engagement through encountering challenges.

According to the individual's skill level, engagement also depends on the difficulty of the task. For instance, in terms of learners, it reflects the confidence that sufficiently improves independent learning. One participant commented: "A bit more of a challenge can drive my motivation to answer the questions. I can easily answer some of the quizzes and get bored. Then, I would prefer some challenging tasks to further improve my learning compared to easier questions." This indicate that the impact on learning in terms of encouragement or reinforcement. This theme came up for example in discussions of repetition could improve their abilities. A small number of those interviewed suggested that they could perceive their ability to handle time pressure while improving learning performance through the appropriate use of time and correct answers. This represents the impact on learning in terms of development and improvement.

Challenge-based gamification provides the ability to improve their knowledge, and the chance for self-assessment, in which using the challenge mechanics provide students better gained their cognitive skill. For instance, participants stated that they had to concentrate on the question since the time was limited. This could be represented as impact on learning in terms of learning concentration. One participant supported this by stating "gamified quizzing provides me the opportunities to realize the background knowledge, and I learned what I did not know, so that made me feel excited."

There were also positive and negative consequences that indicated resistance to engagement in this process. A participant argued: "I could not solve the quiz in the first few questions after I got used to it, so I had to start guessing and considering other options." This is the evidence related to the impact on engagement and learning, both in terms of anxiety and creativity.

3.7.2 Thematic Analysis on Perceptions of Challenge-Based Gamification

The transcribed content in this subtheme focused on behavior change, intervention efficacy, and challenge balancing. Challenge-based gamification was employed to promote desired behaviors and maintain behavior change over an extended period. The effectiveness of challenge-based gamification in supporting this theme was confirmed by interviewees, as indicated by both inductive and deductive interview questions. Participants perceived gamified quizzing with challenge-based gamification positively impacting engagement and learning, as reported in the last two interview questions.

Most participants preferred the time pressure mechanics, as it provided a sense of achievement within a limited time. This emphasizes the motivational aspect and confirms that students were motivated to learn and improve their abilities through this challenging experience. Other responses to this question included: "I could feel pressure when the timer was running. It required concentration and motivation to complete the quiz." This statement indicates behavior changes in terms of motivating behaviors. Likewise, challenge-based gamification made students perform autonomously with the motivation to continue and gain in the learning process. One participant stated: "Winning was not a target when I tried this gamified adaptation. I just wanted to go as far as I could depending on my ability." This statement is also indicative of behavioral changes in terms of sustaining behaviors.

Students found that they could passively engage during easy quizzes, but had to be proactive during more difficult ones to achieve intervention efficacy. One of the participants said, "When the quiz was not too hard, I could focus more and was motivated to face each new challenge as a new learning opportunity." In particular, the challenge and skill relationship mentioned in flow theory could explain the potential of learning opportunities to overcome the current level of performance. This finding can also be represented as allowing learning opportunities. Students experienced diverse sentiments when challenges and uncertainty were added. One mentioned that it was exciting and could allow different students to receive information differently. This finding can also be represented as the efficacy of providing diversity and variety.

The system's progression was based on users' points (correct answers) and levels (difficulty), which helped identify the balance between perceived levels of challenge and skill. Participants reported feeling nervous and unenthusiastic when their abilities were insufficient for the quiz challenges. In contrast, they were more engaged in learning when their abilities exceeded the challenge level of the quizzes. This finding reflects the subtheme of balancing challenges in terms of competence.

3.8 General Discussion

This study's findings indicate that gamified quizzing positively engages students through entertainment and learning by incorporating challenge-based gamification. The findings suggest that a challenge is an essential element and mechanics in game design, providing a basis for further application in the educational context. The study's findings show that the variation in challenge-based gamification positively contributed to the motion in mind concept, as found from the quantitative study. Since the motion in mind concept also contributed both subjective and objective numerical results, the methodology could be strengthened to incorporate a mixed-methods design to overcome some of the method's limitations. We also conducted a qualitative study to understand the subjective matter more deeply in order to strengthen the concept of motion in mind using from support from flow theory construction.

With mixed success in education, exploring the potential impact of gamification in both the engagement aspect and learning aspects is needed to determine the specific terminologies and processes through which gamification is applied to improve learning. Several approaches were investigated by applying a gamified experience in a learning activity in an ungeneralized scientific way [17, 142]. This gap in the knowledge is leading to more studies and discussion on successful gamification. With common ground regarding gamification, some game elements can produce desirable outcomes, which are likely to vary in both the short and long term, depending on the context.

Particularly in a learning environment, an ideal balance between uncertainty and ability is required to emphasize their significance in education and entertainment. Figure 3.8 illustrates

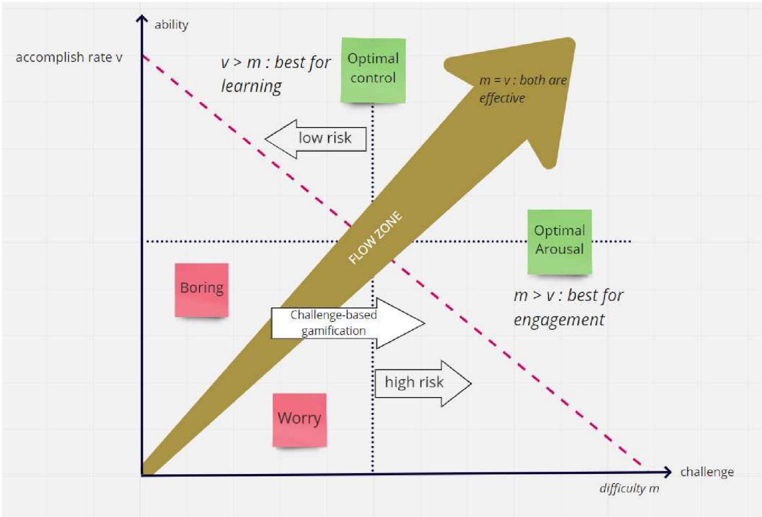


FIGURE 3.8. An illustration of challenge-based gamification related to flow theory and motion in mind

the allocation of challenge-based gamification related to flow theory; each application is open to interpretation regarding each state of the flow, where risk ratio (m) and velocity (v) indicate challenge and ability, respectively. This situation explains the impact of v and m in the transition process of flow where engagement and learning impacts occur.

Figure 3.9 depicts the value of solving uncertainty m regarding the quantity and different kinds of challenge-based gamification. The results show that challenge-based gamification produced changes in the value of m. This implies that complexity or uncertainty can increase competitiveness while increasing objectivity. Time pressure, easy difficulty, medium difficulty, and randomization provided $m \leq 0.5$, which is more intuition-driven than hard difficulty and subgoal pattern. These results show that time pressure and medium difficulty nearly shifted to the flow zone in which individual ability and activity challenge are equal. This supports the conjecture of gamified learning theory [17, 75] that challenge-based gamification can be used to train and enhance the ability of students while providing challenging tasks. The possible outcome can assist the potential significance and functional relevance of gamification learning and student engagement. The intersection point of subjective force F_2 and objective momentum $\vec{p_1}$ indicates high-tension excitement, showing the challenge became harder and therefore required more skill. However, the score may rely on the difficulty and complexity that the student faced during different experiences, which affected the difficulty of solving uncertainty m. This condition shows that the setting proposed in this experiment can be applied to improve the non-gamified condition in the education context.

Our application of challenge-based gamification in a gamified platform's context showed an exciting impact. Our findings imply that this technique is essential for changing behavior, which affects improvements in engagement level and learning performance. However, this study's gamified platform was established in a game context and situated in a gamified experience. The game is balanced in terms of skill and chance regarding flow state transition. Thus, it can also be known as gamification, a practical tool that balances "seriousness and fun" and "educational and entertainment" activity as identified previously [134]. These findings show that gamification should be further developed to provide support in the education domain.

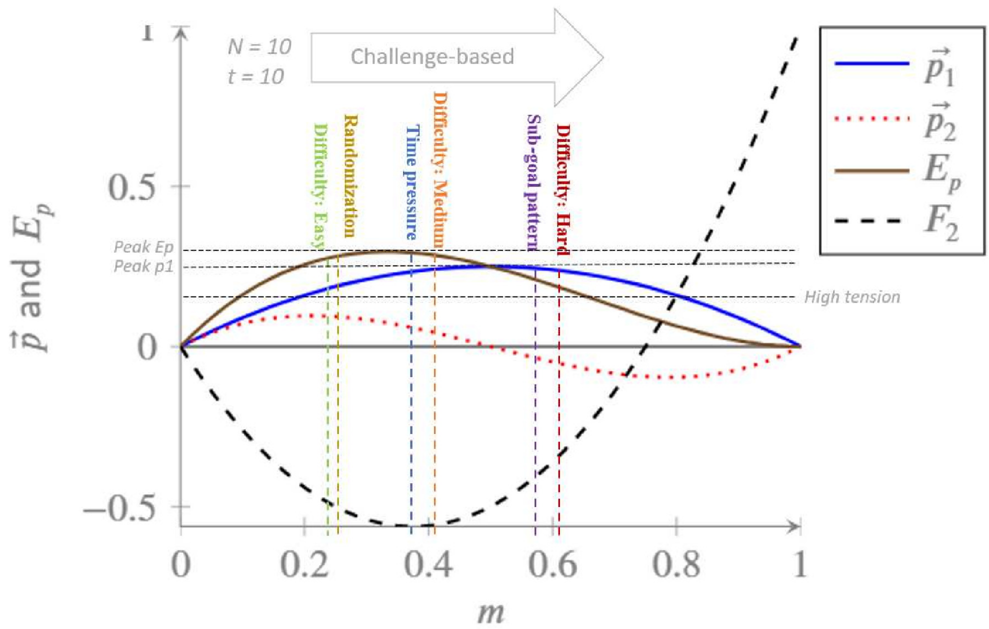


FIGURE 3.9. An analogical measure of the physics of all experiments for various masses m with $N = 10$ and $t = 10$.

3.8.1 Potential Impact and Perceptions of Challenge-Based Gamification

One of the main contributions of this study for game design is that there may be an optimal level of perceived time pressure (as a challenge) provided by adjusting mechanics in games that results in maximum competence and performance accompanied by flow and engagement. This relates to the motion in mind concept and flow theory in which optimal control ($m < v$) and arousal point ($m > v$) are the boundaries for game design elements. Adaptation may produce the optimal control that suits learning in the long term; here, competence level is above the provided challenge. Time pressure, as a challenge, may produce the optimal arousal that enables engagement in the short term; here, competence level lower than the provided challenge. Creating a challenge in the middle of these two zones might be best for engagement- or learning-related outcomes. The results prove that time pressure can foster engagement and motivation in the zone where players experience arousal and anxiety.

According to the quantitative findings, this mechanic produced a greater force and faster pace. The time element was established by motivating players to pursue desirable goals under pressure. This involved increases in arousal and motor activity. This physical aspect was identified through the interview responses, which were evaluated using keywords, indicating that students entered the arousal zone when they were faced with a shorter allowed time. Another finding linking to the motion in mind concept that this mechanic had nearly the least resistance, which could be taken advantage of to ensure student learning performance through ensuring high curiosity and high expectation within the appropriate time limit.

- **Engagement:** Maintaining engagement in an activity should be situated on the lowest F_2 condition, where high E_p holds, which indicates the least learning resistance along with high information expectant. Additionally, as observed in quizzing, a situation lacks engagement when the user is uncertain or skills do not progress Engagement can be promoted by having the right level of initial difficulty, so students can progress relative to their ability. If the task is not challenging, the activity might feel monotonous, so the level of difficulty should increased so that the task is entertaining and gives the player a feeling of worthiness and provides effectual meaning.

  Here, we found that time pressure promoted the gamified activity's motivation, according to the $\vec{p_1}$ value. As observed in Tables 3.4 and 3.5, the $\vec{p_1}$ value was high and gradually decreased during the first phase as the quiz progressed toward the point when the challenge would be adjusted. Additionally, adaptation game mechanics increase user motivation, attenuating the potential impact on engagement caused by uncertainty. When the quizzing involved different challenges with different randomizations each time, the changes ensured the activity remained attractive even though the activity was performed repeatedly. Surprise and uncertainty with unexpected rewards could keep them engaged and maybe even result in intrinsic engagement in the long term [143]. Traditional quiz methods can facilitate engagement by orienting students toward upcoming content and responding to any relevant difficulty. When gamification is adopted, experiencing time pressure may result, as shown in Zeigarnik effect [144], which focuses people's attention on completing unsolved tasks to a certain extent. This unexpected effect has implications for the techniques that we might use to learn and recall important pieces of information. This implies increased engagement and curiosity even in students with high cognitive skills.

Kahoot! is a gamified platform that emphasizes time limits for answering and game mastery. Time pressure may be the primary reason the game keeps its players motivated to play. The initial concept was proposed by [123], who inferred that reducing the amount of time people have to complete tasks motivates them to reflect on the task and can result in various actions. Based on this evidence, the relationship between the student's engagement level in quizzing is proportional to the potential to acquire information. However, it is crucial to focus on the appropriate level of the challenge, the rate of change of solving uncertainty, and the perceived attraction to ensure the game remains exciting. Thus, an ideal balance between challenge and skill makes the game last longer while positively impacting the player. Therefore, the main aim is to produce a balance between educational value and entertainment in games. This can be approximated relative to the reasonable zone measures situated at $m \leq 0.5$, where learners feel under control when the challenge is adequate. Table 3.12 summarizes the interpretation of each motion in mind indicator of the three experiments from the engagement perspective.

Additionally, we applied a mixed methodology to gain additional insights into challenge-based gamification in an educational setting. We found that students perceived various dimensions of engagement. Considering flow theory, one possible explanation is that every zone can provide students with engagement. However, they may experience competition or anticipation during an activity, reflecting a behavior change. Supporting this explanation using the physics value, a general effect could be the possible presence of challenge-based gamification that affirms the potential effect proposed by [17] of the theory gamified learning (game elements influence behavioral changes).

- **Learning:** Since gamification does not directly improve learning outcomes, the sense of engagement contributing to the behavior change emerges [16]. Therefore, learning-related behavior is introduced as an analogical bridge to contribute to the learning outcome [17], emphasizing the development of engagement, which contributes to changing behaviors, where such behaviors generally translate into better learning behavior rather than merely considering the activity outcome. Based on the motion in mind concept, there is still a need to achieve learning-related behavior since each value requires interpretation associated with applying a gamified experience in an education context. The fundamental idea regarding improving learning impact is promoting engagement and the student's emerging potential (i.e., acquiring information). Therefore, students may reveal optimum performance at a moderate challenge level with maximum competence to achieve learning-related outcomes since time pressure creates a challenge. Students' behavior under time limits may be influenced by prior experience, familiarity with the mechanics, and competencies.

  Time pressure benefits students by ensuring decision-making is explicitly developed but increasingly harms decision performance and causes suboptimal decisions, which hinder new information or new strategy acquisition [145]. According to the motion in mind concept, the potential energy value is mostly situated around $m = 0.33$, which implies the least resistance to informational acquisition. Once time pressure is implemented, students tend to encounter risky situations that force students to improve their effort and change their behavior. Other authors [146] showed that time pressure induces a student to perform an activity more efficient.

However, the amount of information load should be centered on the shortcomings of individual students' memories where learning processing is performed, which is supported by [147].

The consideration of uncertainty in challenge-based gamification can result in student performance that captures variations in the motion in mind parameters such as a_2, F_2, and E_p. In this study, we found a more balanced distribution of challenge and preferable ability among the students considering the quizzing impact in the classroom, students' skill levels, and students' engagement levels. For a more superficial understanding, the motion in mind m value was higher when the gamified platform considered challenge adjustment. Challenge levels must be modified and promoted to improve students' skill levels, as a_2 and F_2 are designated as attractiveness and move ability. As described in the literature review section, solving hardness (m) is regarded as the amount of information students able to retrieve, so that a higher m indicates the student was more excited to solve the problem, which improved the learning, as shown in Table 3.12.

Conversely, a lower m value denotes the control state where students can improve their learning without extrinsic motivation (Figure 3.8). The impact on student learning was motivated by perceiving information instead, as described by the increases in a_2 and F_2. As aforementioned, the negative value of both subjective values means students were pushed towards the activity. Thus, the best conditioning for learning purposes occurs if game elements and well-designed mechanisms are incorporated. We interpret this impact as students feeling a sense of achievement, which reflects learning improvement. The game elements in the current study potentially encouraged students to change their behavior depending on the difficulty of the quiz, as indicated by quiz performance and our quantitative analysis. This supports the qualitative analysis where students provided responses regarding the outcome of the challenge-based design. However, we only applied a quiz with a logical puzzle that was independent of individual skill. As such, we advise caution when interpreting the findings; further studies are required to support these findings.

TABLE 3.12. An interpretation of each motion in mind indicator for the three experiments from an engagement perspective

Experiments	**Indication**	**Interpretation**
Time pressure	$m \leq 0.5$ and $\vec{p_1}$ Negative peak F_2 and positive peak E_p	Maintain engagement Least resistance, high curiosity
Challenge adjustment	balancing m Peak$\vec{p_1}$ and E_p	Appropriate difficulty depending on the skills Growth rate and stronger motivation
Adaptations of pattern	$m \geq 0.5$, $\vec{p_1}$ and E_p a_2 and F_2	Hard to maintain engagement Negative value arouses students to increase effort

Participants acknowledged that these interventions are relevant to the motivation and learning process and perceived them as pressing and challenging. The effectiveness of challenge-based gamification is indicated because participants considered the game elements available to them fit their preferences and mentioned that the challenge-based gamification conveyed a sense of flow and curiosity. Also, when using the challenge-based gamification, participants felt the dynamical experience and uncertainty that possibly led to the improvement in the learning process and reinforced the motivation.

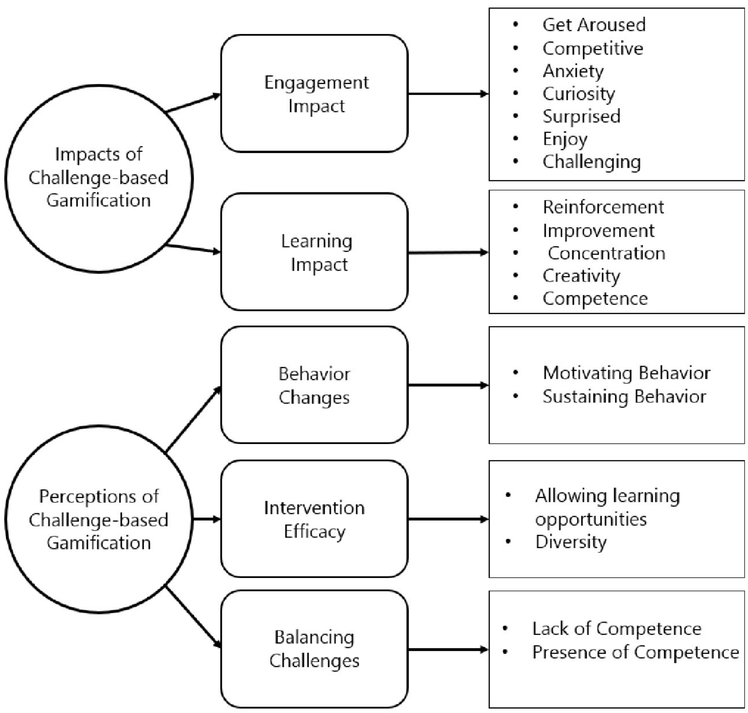


FIGURE 3.10. A thematic map showing themes, subthemes, and codes.

Figure 3.10 shows the organization of themes, subthemes, and codes, with themes in ovals, subthemes in rounded rectangles, and codes in rectangles. The codes were distributed into five main subthemes, which were distributed into two main themes: (1) impacts of challenge-based gamification and (2) perceptions of challenge-based gamification. Of the five subthemes, two subthemes were clustered under the first theme (impacts of challenge-based gamification): (1) engagement impact and (2) learning engagement. The remaining three subthemes fell under the second theme (perceptions of challenge-based gamification): (1) behavior changes, (2) balancing challenges, and (3) intervention efficacy.

The mass value m denotes the risk chance, with a higher difficulty indicating a lower chance of achieving their desired goals. Here, we found a related basis in flow theory, which specifies a zone of balance between challenge and competence. Levels contain specified elements that create the difficulty. Once the challenge is applied, motivation increases. The motivation level decreases with increasing difficulty, which reflects a high value of m. This indicates that difficulty adjustment provides temporal motivation. After the users attempt the harder challenge, they become bored quickly due to the value of force F, potential energy E_p, and momentum $\vec{p}$. This creates high resistance, resulting in a negative force value, experienced by the student as anxiety and frustration. Therefore, the qualitative findings showed that a sudden increase in challenge level is effective in the short term. To produce long-term results, more than one game element must be incorporated or game mechanics must be adapted.

These results depict the emergence of curiosity, as new pieces of information provide incentives. Cognitive curiosity was exhibited that forced the students to perform flexibly given the uncertainty. According to motion in mind, we proved that quantitative results indicate the relationship between challenge and allocated time. Our qualitative studies proved the conjecture in two ways: First, students enjoyed the process, but engagement was easily lost. Therefore, the appropriate opposing force can take full advantage of the engagement potential. Secondly, opposing forces can result in the decline in learning potential.

Therefore, the results of this qualitative experiment reinforce the theories discussed in this paper. We also found a supplementary result that supports the positive impact of gamification the adoption of game elements, remarkably increasing the dynamics of the elements by adapting the game mechanics with several game elements and finding the optimal prototype of the gamified platform. This ensures with challenging game designs that lead to the use of game elements in the educational classroom.

3.8.2 Practical Implications and Theoretical Contributions

This study addressed the research gaps regarding gamification techniques' impacts on learner motivation and engagement. In our study, we discussed student engagement using quantitative findings based on the motion in mind concept outlined by physical values such as velocity, acceleration, momentum, and energy [26]. Considering this, the study's findings contribute to developing the understanding of this concept by incorporating challenge-based gamification into quizzing, with additional support from qualitative data based on flow theory.

The findings of this study have two potential practical implications for educational stakeholders: First, the implementation of gamification has benefits in terms of enhancing learning-related behavior. The concept of gamified learning helps the learner and instructor through the learning process, providing engagement and literacy skills. A conceptual scheme was proposed to determine the impacts of gamified learning experience and assessment for the evaluation of learning-related behavior.

Figure 3.11 illustrates this study's input–output process of gamification on a gamified platform. The model represents the process of gamification, in which game elements and instructional content are input to drive behavioral changes and engagement. Gamification influences students and their behavior. As such, it often seeks to build upon the increasingly ubiquitous role played by games as an entertainment medium to provide an engaging method to deliver educational content and thus to shift behavior. Our findings and proposed game mechanics can make games particularly appealing as a tool for analyzing and capturing impact by using quizzing. Subsequently, classroom activity can be gamified either for individual users or to comprehensively understand the efficacy of interactive tools. The concepts of challenge-based gamification should be addressed to achieve motivation, which refers to the individual's willingness to remain involved and learning, and the experience of flow. It exhibits the relationship among constructs described in the model and indicates how gamification is intended to influence such outcomes.

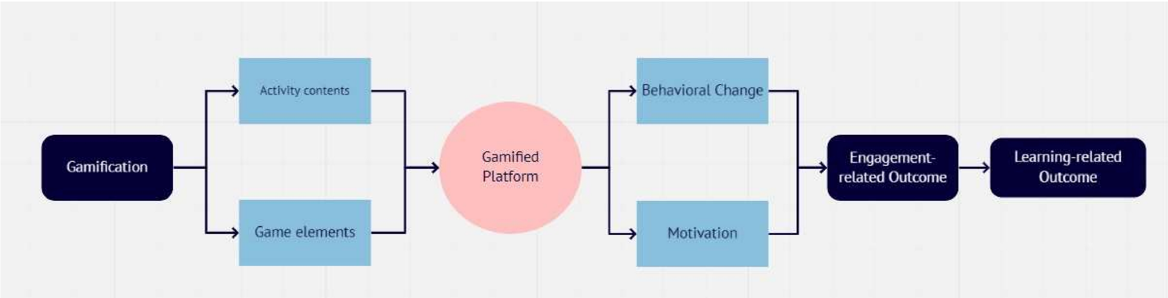


FIGURE 3.11. An input–output process of gamification in a gamified platform

The application of the gamification process involves considering the design process, including which game elements address the target behavior, and this behavior must have an impact on learning. It specifies that the motion in mind measures the game context related to entertainment and attractiveness, which reflect the engagement aspects. Learning improvement could be encouraged if behavioral changes and motivation occur [17]. Thus, both induce learning-related behavior, which affects the capability to improve learning due to gamification. Once motivation is obtained, the result of this improvement is then achievable via effective settings. These experiments provide different gamified learning results and outcomes, but further analysis and designs are needed to support this process.

Similarly, challenge-based gamification can capture its impact on both engagement and learning. With the findings of our studies revealing each game design element's contributions to the challenge experiences, other game elements can be considered and we showed how the these elements can be designed. The mechanics proposed in this study reveal the existence of an optimum time limit, number of questions, and difficulty level through which players experience the flow zone and perform at maximum competence. Moreover, the gamification's features are reflected as mechanic adaptation, which affects students situated in the dynamic zone, which would be useful to promote creative thinking and other meaningful purposes in the education and entertainment contexts. Therefore, stakeholders can benefit from this framework and our approach in this study to create classroom activities to ensure player engagement, achievement, and learning purposes. We provided a promising and innovative method to engage students to learn skills and feel a sense of achievement. This study's findings may help schools transform classroom activities to encourage and retain students' motivation and engagement while challenging and entertaining them.

3.9 Chapter Summary

Challenge-based gamification provides a precise approach that examines which element contributes to learning and induces a specific outcome. From this study, we used challenge-based gamification in a quizzing activity to encourage student motivation based on motion in mind interpretation. First, we examined the impacts of time pressure and difficulty on the feelings of curiosity and uncertainty. Both ultimately affected the engagement- and learning-related outcomes of applying quizzing and educational content into a gamified platform. The motion in mind concept proposed here provides measurements of engagement, motivation, and the nature of the mind in various contexts and from various perspectives. This approach identifies two specific methods through which gamification can moderate experiences and affect a learning-related behavior.

Our findings also showed that gamified quizzing improves classroom activity by referring to flow theory since the challenge shifts students' experience into an arousal zone, which subsequently transforms if the challenge and students' abilities are encouraged, which can be achieved using the gamified elements proposed in this paper. This shows that the learning performance improved, as represented by the learners' performance metrics, leading to learning impact being situated in the control zone. Thus, we strongly recommend that further studies be conducted in order to implement such dynamic gamified quizzes with other gamification designs and elements to support the understanding and the transition of engagement- and learning-related behavior in the education context.

There are at least two limitations of the current study. First, the challenge-based gamification approach was confined, as mentioned in the methodology section. Therefore, it is difficult to determine which of these components had which effects.The game elements' and our proposed experimental designs would display the different effects of different interpretations.

This study may be justified by its internal validity since the proposed design can be used to verify the cause-and-effect relationship established in a study. Nevertheless, external validity could not be achieved since we did not have enough results and the sample size was too small for comparison with other cases. As such, this limitation suggests caution when interpreting the results since such findings were not externally validated, requiring further investigation. Future studies should also consider complex details when designing engaging gamified activities and experiments in educational settings.

Secondly, we aimed to bridge the gap between motion in mind and flow theory. The proposed interpretation might work in the current circumstances, but it may not work for different mechanisms. Our findings may require an extension of underlying psychological analysis or dynamic mechanisms to provide insights into entertainment and learning experience through gamification to highlight this limitation. A future study could investigate the use of a dynamic approach: a more objective method that can be seen explicitly, or a complex methodology, including specific artificial intelligence coping with different participants.

CHAPTER 4

Objectivity and Subjectivity in Variation of Multiple-Choice Questions

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This chapter is an updated and abridged version of work previously submitted under peer-review in

- Punyawee Anunpattana, Mohd Nor Akmal Khalid, Hiroyuki Iida: Objectivity and Subjectivity in Variation of Multiple Choice Questions: Linking the Theoretical Concepts using Motion in Mind, Heliyon (Under peer-review).

4.1 Chapter Introduction

This chapter outlines the results of various types of multiple-choice questions (MCQs), which consolidate theoretical concepts better to understand objectivity and subjectivity in an educational assessment using motion-in-mind perspectives. Multiple-choice questions (MCQs) have been considerably used for assessing the individual's performance in various contexts. The optimal number of options in MCQs is a debatable issue, followed by contradictions and discussions. It is needed for a firm conclusion from empirical and hypothetical findings in several depths. The theoretical concepts, including challenge-based gamification, zone of proximal development, and prospect theory, were proposed to analyze and generate insight into educational assessment using motion-in-mind measurement. Classical test theory (CTT) was used to determine reliability and validity. MCQs were experimented with: the number of options, settings, and scoring methods. The experimental data was gathered from human and AI simulations and measured using motion in mind. This study revisits the notion of learning comfort based on the motion-in-mind perspective, mainly because this study aligns the reinforcement and curiosity interpretation with serving the education context. At the end of this chapter, the results addressed the general discussion, which helps link analogical interpretation in the education context based on physics-in-mind values. The findings can be an extension study for analyzing the learning process and marking the learning process from objective and subjective points of view.

4.2 Related Works in the Educational Assessment

4.2.1 The Optimal Number of Option

Much research into MCQs has focused on the number of options in the multiple-choice questions. The ongoing issue raises whether there is an optimal number of options for items in MCQs to utilize and how to apply them correctly to different educational levels and specific contexts.

According to empirical research, the optimal number of options has become vital in considering well-known standardized test settings. The previous study hypothesized that the reliability of a test would increase with the number of options per item where the number of items remains constant [148]. Following [149], they suggested that more options improve the reliability of the test. Thus, the general guideline is to materialize as many options as possible [29]. However, there is research literature determining the optimal number of multiple-choice questions using several mathematical approaches consistent with the 3-options items. The authors demonstrate that it is better to set the number of options as 2- or 3-options in terms of being full of information and power under certain conditions (without concerning external factors). They showed results in which value has been represented in terms of improved reliability [150][151], and information efficiency [152][153].

Most literature was experimental, with forms of a varying number of options randomly assigned to individuals. It is pretty challenging to establish test items in order to avoid the effect of guessing and distortion in ability evaluation. Nevertheless, solving this research was demanding because studies examined different numbers of options, generally some combination of 5 options to 2 option items. The previous study stated that the 2-option version of the test was the easiest and least reliable, with the difficulty of the formats increasing with the number of options, and concluded that the optimum number of options was more significant than three [154]. However, [155] argued that reducing the number of options caused a significant change in mean item difficulty (item easier), obviously in 2 options. The study revealed that in most cases, reducing the number of options resulted in a decrease in the amount of reliability due to the most significant item discrimination index. Furthermore, it is supposed that with a more significant number of options per item, the probability of getting an item correctly without sufficient knowledge, i.e., the guessing factor, would decrease. The issue was also continued in [156] that compared the performance of 3- and 4-option items from the English university entrance examination. They inferred that 3-option tests are not significantly different in either their difficulty or their discrimination ability from the 4-option equivalents, nor was the reliability of the test markedly decreased by deleting one option. There was no difference in the difficulty of the items in the 3- and 4-option. In other words, the study revealed that the 3-option MCQ works nearly as well as the 4-option MCQ.

In practice, MCQ usually contains 4 or 5 options per item, particularly in standardized testing according to [29, 157]. A large body of research on how determining the number of options impacts test quality has approached the issue from several aspects. This research also discusses how the number of options in the multiple choice questions affected those changes and compares the effect on validity and performance noticed among the multiple choice things with varying numbers of options in Thailand [158].

Investigation of three response options provided the optimal balance between psychometrics quality and efficiency of administration [155]. The previous research suggested that it is better to reduce to two options if one option can be removed by applying knowledge to individuals [29]. However, the literature favors three-option multiple-choice; four-option multiple-choice is conventionally used in many medical schools and national examinations where the dominant trend is toward objective tests. Using three options is optimal in theory, but a more considerable number of options would increase the content of variability of test results [159]. The study found that the 4-options format is the optimal number with simultaneous development of a good test content outline and improved reliability [159]. [160] stated that the 5-option format is suitable if the distractors are well-constructed. A comprehensive study of the number of options claims that fewer options result in a relatively easier test. The relevant studies found that the test difficulty significantly differed between three-, four-, and five-options [161, 162, 44]. Considering all that has been mentioned, determining the optimal number of options is critical in evaluating learners in the educational context. The number of options in MCQs may or may not be optimal depending on stakeholders considering several other factors in determining the optimal number of options for a specific context. However, the results of different studies are contradictory. As is evident in most of these studies, many relevant studies have been provoked by needing a firm conclusion from empirical and theoretical findings. It is necessary to review the practical discussions in their favor to support their worth.

4.2.2 Incorporation of Gamified Affordances

The goal of developing a multiple-choice question should be to design a set of questions that challenge students while also allowing them to achieve a reasonably high level of achievement. Extremely simple or complex multiple-choice tests are useless for assessment and learning. Promoting engagement is essential since it facilitates learning and the learning process, leading to more effective implementation in educational practice. One example is incorporating game elements like gamification and practical techniques to facilitate short-term and long-term learning potential. Gamification is rapidly being used in educational contexts to boost student motivation, and learning outcomes [27, 73]. The previous study showed that students who completed gamified quizzes completed more quizzes and revealed higher learning due to the testing effect. The findings corroborated the testing effect, which showed that students who completed more quizzes fared better on subsequent assessments. Gamified learning tasks improve our understanding to support the long-term benefits, and its outcomes justify both positive and negative ways for producing the learning process.

According to Deterding et al. (2011), employing gamification in various backgrounds can enhance the individual's motivation. Many Researchers have proposed some method embodiments for applying gamification approaches in educational situations. Most works studied the effect of gamified elements on testing or quizzing activities as mentioned in [73].

Difficulty settings of questions are also essential to support the individual's motivation. When questions are an appropriate difficulty for each learner, learners can feel a sense of accomplishment and self-growth. This eventually causes the learning process and enhances an individual's motivation to learn. [163] developed the system to estimate the appropriate difficulty. [164] also developed the algorithm to estimate ability in language topics based on responses to test questions and selects new content to maximize learner improvement. Therefore, most educational games are adaptive games that constantly adjust difficulty levels to individual players' skills. [165] mentioned that rewards would help individuals evaluate their assessment and ensure confidence in the learning process. A task is a question or problem in the game to help learners to absorb the learning content, which should be designed with different levels. Feedback minimizes the individual's misunderstanding and provides self-assessment during the task. Feedback and task are vital in education and are emphasized in various designs. The developed application aggressively supports the learners' sustainable motivation through gamification techniques and an efficient difficulty-setting method [165]. Students performed a multi-part programming task with the support of scaffolding and gamification as implemented in gamified learning system [166]. Results were shown to improve the individual's performance in programming as they progress through assignments.

Nevertheless, while research on the usefulness of gamification in education is advancing, there needs to be more literature on which types of gamification could be beneficial for specific educational contexts, including the theory of gamified learning proposed by [76, 17]. With the growing popularity of gamification, the type of gamified learning activities is needed to justify the evidence supporting the long-term benefits and its education practice. Implementing gamification and scaffolding in multiple-choice questions is expected to maintain learners' short-term motivation; however, the learner should discover a pleasure or a purpose of learning to keep their long-term motivation.

4.2.3 Scoring Methods

Around the 1970s, small-scale research and case studies focused on scoring methods. The vast majority of studies on scoring methods were mentioned as formula scoring. [167] pointed out that expected formula scores are a linear function of expected number-right scores. He proved that if random guesses replaced omissions under formula scoring under number-right scoring, the formula scores would be superior estimators of an individual's ability. [168] presented the effect of formula score, which provides the extent of the motivation for preferring between scoring rules.

Scoring methods in MCQ tests have been studied extensively to improve their psychometric properties, including reliability and validity [106, 107, 108]. The way in which questions are scored can create framing effects that influence test takers' risk-taking behavior and guessing tendencies, which in turn can impact the validity of the assessment. Decision-making in the presence of uncertainty is closely related to the general framework of prospect theory [102]. Different scoring rules in MCQs may induce various frames for the same question, influencing test takers' behavior and knowledge levels. To assess these framing effects and their impact on the learning process and risk-taking, this study proposes the motion-in-mind model applied to MCQs.

4.3 Item Analysis: Classical Test Theory

Item analysis is essential to improving item characteristics, which can eliminate ambiguous or misleading items in a single test administration.

Most scholars study item characteristics based on Classical Test Theory (CTT). Two basic indices are used to systematically evaluate the effectiveness of individual items in a norm-referenced test: item difficulty and item discrimination. It utilizes nothing more complicated than proportions, averages, counts, and correlations. For this reason, it is helpful for small-scale exams or uses with groups that do not have psychometric expertise [169]. This study employs the classical test thoery (CTT) model rather than other test theories (e.g., Item Response Theory) because this theory is viewed to be more flexible and trustworthy [170].

As part of our experiment, a purposeful mix of 3-options to 5-options MCQ were selected from the item pools. The classical test theory arbitrarily categorized criteria for determining easy, moderate, and difficult items. The theory quantifies item difficulty and discriminability by item's scores to the test's total score.

TABLE 4.1. Difficulty indices and discrimination indices on our proposed question items

	3-options	4-options	5-options	Total
Easy	33	0	0	33
Moderate	44	106	10	160
Hard	0	43	64	107
			Total	300

Strong discrimination	70	150	34	254
Fair discrimination	7	10	10	27
Poor discrimination	0	10	9	19
			Total	300

4.3.1 Item Difficulty

Item difficulty or item facility refers to the percentage or proportion of test takers who answered an item correctly in a given test [171]. It ranges from 0.00, which signifies that the item in the test was challenging, to 1.00, which shows that the item was straightforward. A functional discriminating item must have appropriate difficulty levels, and each distractor must have the feature of plausibility.

As part of our experiment, question items in the pool have total of 300 items, combining 77 items of 3 options, 170 items of 4 options, and 53 items of 5 options. Participants are asked to complete all question items. The item difficulty is merely the percentage of participants who answer an item correctly. In this case, it is also equal to the item mean, which can be calculated by dividing the number of participants by the total number of participants. The item difficulty index ranges from 0.00 to 1.00 (or 0 to 100%); the higher (lower) the value, the easier (harder) the question. In this study, we define that all the question items are marked dichotomously. Participants will achieve one point for the best single correct answer and no point for choosing distractors (incorrect answers).

Table 4.1 visualizes the scores achieved by the 3-option group were higher than those of the 4-option group, which were more significant than those of the 5-option group. We arbitrarily classify item difficulty as easy if the index is 75% or above, moderate between 51 and 74%, and hard if it is 50% or below. Moreover, it displays the difficulty index values based on the proportion of the number of correct answers in each session against the total number of participants. Hence, the proposed question items consisted of 33 easy items, 160 moderate items, and 107 difficult items. In deeper detail, all 33 easy items are accumulated from the 3-options group; 160 moderate items are accumulated from 44 items from the 3-options group, 106 items from the 4-options group, and 10 items from the 5-options group; Also, 107 moderate items are accumulated from 43 items from the 4-options group, and 64 items from the 5-options.

4.3.2 Item Discrimination

Item discrimination refers to the ability of an item to differentiate between low-ability and high-ability test takers, notably contrasting test takers with greater mastery of the to-be-learned skills and knowledge from those with less mastery. The discriminability of a test item depends on its difficulty level and mainly on the degree of plausibility of its distractor [171]. The more significant difference interprets as a contrast between upper and lower groups of test takers, in which positive and negative values can be obtained depending on the performance of upper and lower groups. Item difficulty reflects how difficult or easy an item is and is numerically expressed as the proportion of students who answer an item correctly.

The procedures have traditionally been used to compare item responses to total test scores using high and low-scoring groups of students. To be clarified, participants were divided into higher and lower ability groups of 27% each for various options formats, in which upper and lower groups are counted as 12 and 12, respectively. A discrimination index (DI) was established for each item based on the number of correct answers in the upper group less the number of correct answers in the lower group, with the product divided by the participants in each of the higher and lower groups. This study classifies item discrimination as good if the index is above 0.30, fair between 0.10 and 0.30, and poor if it is below 0.10. Items with negative indices should be examined to determine why a negative value was obtained. For instance, the item was a mistake, or participants may get confused, but they respond correctly.

According to Table 4.1, it visualizes that 254 items hold strong discriminability, 27 hold fair discriminability, and 19 hold poor discriminability. This implies the evidence that the discriminability of test items relies on the number of options, a tendency to guess or misunderstand the item's key increases, as well as the number of options and difficulty.

4.4 Methodological Assessment

Participants completed 300 multiple-choice questions with 3-, 4-, and 5-options. The MCQs in the study's item pool were gathered from TOEIC test assessments from Cambridge, Oxford, Barron's, and Longman's textbooks. In each test, the item stems were identical. Participants were encouraged to respond to all items, even unsure ones. They did not know the feedback of their responses and were not able to indicate correct response at the time, only total points were given, to avoid recall and rote memory that may burden the quality of results.

Several lines of evidence [172, 173, 174] have presented 4 or 5 options for high-stakes assessment, while 3-option MCQs are advised for classroom-based assessments and achievement tests requiring more knowledge to be taught in a short period. Our proposed experiment was thus that of a standardized external examination as suggested in the literature. A time limit of 30 minutes was provided as a baseline in the variation of MCQ sections. An example item is illustrated as below.

EXAMPLE 1. *This is the example of the multiple-choice cloze test question used in this study.*
***Stem**: Being a wise politician, Mr. Brown tends to reserve his .... till he knows all the*

facts.

Key & Distractors

A. benefits B. bookings C. appearances D. judgements

4.4.1 Motion-in-Mind Model

In the current context, v generally means the rate of solving uncertainty. In contrast, m implies the difficulty of solving such uncertainty($m = 1 - v$). As such, both v and m are determined by the following [26].

Let B and D be the average number of possible moves and game length, respectively. Solving rate v is approximated as 4.1, by which v is equivalent with the slope v of game progress model in 2.7.

$$v = B/2D \tag{4.1}$$

Let G and T be the total number of goals and attempts per game respectively. Scoring rate v is given by 4.2, where the slope v of the game progress model in 4.2.

$$v = G/T \tag{4.2}$$

Then, interpretation in the education context can be inherently conducted. Considering the objective velocity v_0 and mass m, they are the scoring rate for the objective and hardness rate, respectively. Velocity v_0 holds on the function of mass m, given by the equation $v_0(m) = 1 - m$, which k equals 0 (i.e. perfect player). As such,

In this study, correct response corresponds to obtaining a reward. It implies the test length, D in board games (total number of plies), and scoring games (total points or total question items). Hence, $N = D$ or $N = T$, implying a general form of reward frequency of the test's scoring rate. Based on such a notion, the scoring rate v_0 and scoring hardness m is defined by 4.3.

$$v_0 = \frac{1}{N} \ and \ m = \frac{N-1}{N} \tag{4.3}$$

This study adopts an MCQ paradigm based on the VR schedule to establish the link between learning and playing. This approach utilizes motion-in-mind measures to propose the underlying relationship between the VR schedule and the number of options N in the MCQ.

The fundamental element was measuring the mass and velocity, enabling the derivation of force F as an effort ability to drive to achieve a high score, momentum $\vec{p}$ as the degree of confidence influenced by test fairness, and potential energy E_p as the potential motivation to do an activity. Intuitively, Table 4.2 illustrates an analogical link that relates physics in mind notations of game and education context [26].

TABLE 4.2. An analogical link that relates physics in mind notations of game and education context

Notation	Game context	Educational Context (MCQ)
y	Solved uncertainty	Scores/Points
t	Progress or Length	Total score from all items
v	Solving rate	Scoring rate, Item facility (Easiness)
m	Solving hardness	Missing rate
g, a	Thrills	Time pressure, Perceived difficulty
F	Move ability	Effort
$\vec{p}$	Move intensity	Test Fairness
E	Move potential	Motivation

Based on the interpretation of solving hardness m to the player's ability k, the subjective velocity of the player (or individual) with ability level k is denoted mathematically as the following equation. The subjective velocity v_k is varied by ability level k. The larger k means the player has less ability, while the smaller k means the player has a higher ability. The subjective velocity of the player (or individual) with ability level k is denoted mathematically as the following equation 4.4.

$$v_k(m) = (1 - km) \cdot v_0 \tag{4.4}$$

The notion of energy conservation had been proposed as a potential measure of engagement and curiosity, where the potential energy in the mind or subjective energy E_k is given by 4.5.

$$E_k(m) = 2mv_k^2(m) \tag{4.5}$$

As respect to mass m, the subjective velocity v_k and subjective energy E_k will become zero when the ability of the individual holds at $k = \frac{1}{m}$. The motion-in-mind measures such as v_k will generalize $\delta_k = v_0 - v_k = kmv_0$, representing the competitiveness. While the reinforcement difference ($\Delta_k = E_0 - E_k$) can be depicted as extrinsic and intrinsic motivation difference.

4.4.2 Reliability

TABLE 4.3. Concurrent validity based on the correlation between TOEIC and scores in our proposed MCQ, and $KR-20$ reliability coefficients of the experimental tests

	3-options	4-options	5-options
participants (n)	48	48	48
No. Questions	30	30	30
TOEIC scores	53.33	53.33	53.33
No. Questions	77	170	53
mean scores	56.25	89.65	17.92
mean scores (%)	73.05	52.73	33.80
Correlation coefficient (r)	0.964	0.986	0.981
significance (p<)	0.0001	0.0001	0.0001
$KR-20$	0.95	0.97	0.79

Cronbach's alpha is an essential tool for measuring the strength of internal consistency [175]. This refers to how closely a set of items are as a collective. It can also be defined as the measure of scale reliability. In other words, it is defined as the purpose of the number of items in a test, the average covariance between pairs, and the total score variance. They are widely used to quantify the reliability of reporting research scales and survey questionnaires. Also, we can compute the reliability of the binary scale, which is a valid question scores one, and an incorrect question scores zero, by conducting an analysis known as the Kuder-Richardson 20 formula ($KR-20$) [175]. This index checks the internal consistency of measurements with dichotomous choices. Cronbach's alpha is usually reported in scales ranging from 0-1, with the larger values representing more reliability. Inherently, Cronbach's α of 0.7 or higher is usually considered acceptable, while too high a value (above .90) indicates a homogeneous test.

The coefficients $KR-20$ for the three formats are shown in Table 4.3. The coefficient for the 4-options format is the highest, while the 5-options format is the lowest. However, all coefficients are situated above 0.7, which is acceptable. The coefficients for the 3-option and 4-option formats were very close, lying between 0.87 and 0.89. The coefficient for the 5-option format was somewhat lower, mainly due to the small number of items and more considerable variance among the scores.

4.4.3 Validity

Consideration of the validity of the MCQs detailed in this paper was primarily aimed at showing that the construct being measured by the experimental tests was broadly similar to that measured by the Reading Part 5 of the TOEIC test, which consists of 30 items, and was therefore confined to a comparison of the correlations between the overall scores of the 48 participants the three types of multiple choice format in the TOEIC test and their experimental multiple choice test scores. The TOEIC test initially consists of 4 options, and test takers are asked to choose the single best answer among all options. The test result will be used as criterion reference data against which comparison of the experimental tests. According to the number of question items in the experiment, we generalized the score of each session into a percentage in order to calculate the correlation between the two tests. Pearson's correlation is introduced to determine the correlation coefficient between practice and experimental tests. Then, the correlation coefficient (r score) and significance p-value were calculated.

As can be regarded from Table 4.3, the correlation coefficients between the 4-options MCQs TOEIC in the reading part and their respective scores in the three experimental tests were all significant at the 0.00001 level. The 3-option format had the lowest value, while the 4-option group had the highest due to the criterion reference test being in the 4-option format.

4.5 Analysis of Variations in MCQ

The conceptual framework (illustrated in Figure 4.1) combines the factors affecting the learning process with the learning process driven. The relationship combines the factors and learning process driven. Several factors are mentioned, including learning objectives, learning style, learning environment, reinforcements, intellectual level, mental level, and balance between challenge ability. It provides an effect on curiosity, motivation, and cognition.

Participants answered 300 multiple-choice questions with 3, 4, and 5 options. The MCQs in the study's item pool were taken from TOEIC test assessments in Cambridge, Oxford, Barron's, and Longman's textbooks. The first step in this analysis was to address the effect of variation in the number of options and findings related to the motion-in-mind concept. Following the first analysis, the analysis incorporated challenge-based gamification and scaffolding in the MCQ context. After that, the analysis of the scoring method was investigated to find the relationship between the framing effect and the nature of motion-in-mind. The experiment addressed the workflow design and how to assess the individuals' performance based on the game design elements and motion-in-mind perspective.

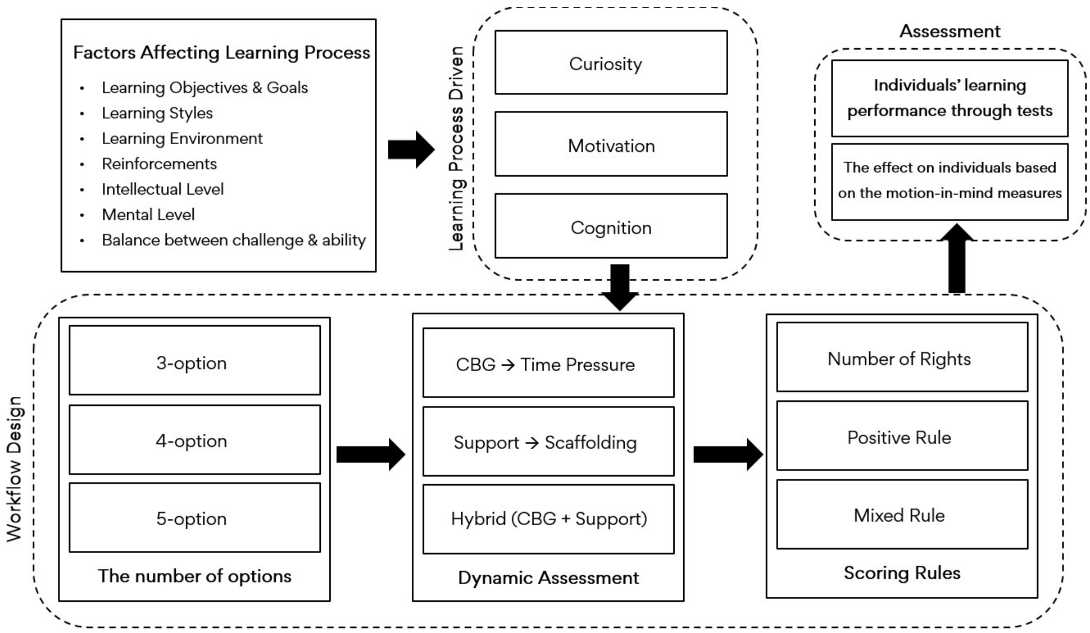


FIGURE 4.1. A conceptual workflow for analyzing the learning process used in this study.

4.5.1 Variation in the Number of Options

In guessing terminology, the guessing rate is defined as $1/N$, where N is the average ratio of the number of options. This means that the average of N plausible options in the test would be the correct answer. For example, the probability of choosing the desired response by random guessing decreases from 0.5 for 2-option items (such as true or false items) to 0.33 for 3-options MCQ to 0.25, 0.20, and 0.17 for 4-, 5-, and 6-options items, respectively. In fact, the chance to answer correctly depends on the number of options. The deeper detail claims that only two possible correct or not scenarios exist. This implies that the success rate is defined as the number of correct answers over the total question items.

This study commenced with two game progress models introduced by [26, 110]. Assume that participants have partial knowledge of English subjects. The data collection was conducted through raw data of $n = 48$ participants. The number of options in the test can be reduced by gaining knowledge. The intuition is based on the transition of the chance-based scenario to a skill-based scenario. This corresponds to the move selection model in board games. However, examination, test, or quiz are the assessment method that evaluates performance based on the score. This corresponds to the score progress model, usually used in sports games (scoring games).

The measurement of motion in mind was conducted to compute all data. Table 4.4 illustrates the experimental data on the motion in mind values of v_0, m, $\vec{p}$, E_0, and N.

TABLE 4.4. Motion in mind measures of three experimental multiple-choice question formats based on the partial knowledge

	No. Questions	**Mean Scores**	v_0	m	N	E_0	$\vec{p}$
3-options	77	56.25	0.73	0.27	1.4	0.2876	0.1968
4-options	170	89.65	0.53	0.47	1.9	0.2629	0.2492
5-options	53	17.92	0.34	0.66	3	0.1513	0.2237

Prior, the least success rate v_0 was the 5-options format (v_0 = 0.33). Then, the most success rate v0 was the 3-options format (v_0 = 0.73). 4-options format contained the success rate v_0 at 0.53. In response to 3-options MCQs, the experimental results indicated the objective energy E_0 was 0.2876, the momentum $\vec{p}$ was 0.1969, and the average number of options N was about 1.4. The analysis showed that participants will encounter the event that similar options in MCQ existed, they achieved more than 70 percent of correct responses. In response to 4-options MCQs, the experimental results indicated the objective energy E_0 was 0.2629, the momentum $\vec{p}$ was 0.2492, and the average number of options N was about 1.9. The analysis showed that the event is close to having a chance to select one out of two plausible options, where ability and chance are balanced. In response to 5-options MCQs, the experimental results indicated the objective energy E_0 was 0.1513, the momentum $\vec{p}$ was 0.2238, and the average number of options N was about 3. The analysis showed that three out of five options must be successful. It indicates that the event is equivalent to guessing among three options, where participants achieved more than 33 percent of correct responses. Figure 4.2 illustrates the motion in mind measure with respect to mass m with k=3.

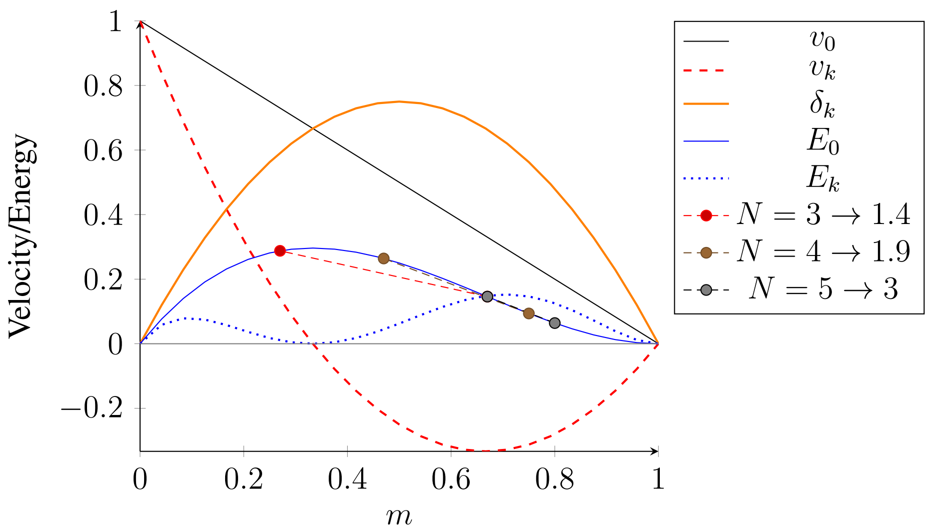


FIGURE 4.2. Measures of motion in mind with indicator of N for $k = 3$

To validate the results, the experiment were run using AI simulation written in Algorithm 1 (see Figure 4.3 to performed the test from our proposed question items. It interprets the success rate as a probability for an individual to answer the test correctly. The outcome relies on the individual ability and branching factor, which is the number of options. The agent's algorithm followed the guessing terminology, in which the agent will be assumed to have partial knowledge of the questions. Then, the agent will encounter the questions and try to guess based on the probability of each node, namely options. To simplify the calculation and given that we deal with hypothetical questions, we bound the ability level of the agent to not knowing at all. For this case, the probability of being correct equals $\frac{1}{N}$, where N=the number of options. The probability of being correct with partial knowledge is greater than $\frac{1}{N}$ until 1. The results were collected from analysis and simulation 2400 times, where the velocity v_0 was computed based on different ability levels of the agent.

Algorithm 1 MCQ AI with various level of knowledge

```
Result: success rate v0
Input Assign Key Option with 1 points, question items
initialization
Sample ← 2400
N ← 300
TotalPoints ← 0
for x ∈ Sample do
    Sum[x] ←— 0
    for y ∈ N do
        p1 ← random probability ∈ [0.33, 1]          ▷ *3-options
        p2 ← random probability ∈ [0.25, 1]          ▷ *4-options
        p3 ← random probability ∈ [0.2, 1]           ▷ *5-options
        Key Option ← p1, p2, p3
        A[y] ← A Selected Option
        if A[y] contains 1 then
            Sum[x] ← Sum[x] + 1
        else
            Sum[x] ← Sum[x] + 0
        end

    end
    TotalPoints ← TotalPoints + Sum[x]
end
Avg ← TotalPoints / Sample
success rate v0 ← Avg / N
return success rate v0
```

FIGURE 4.3. Algorithm 1: MCQ AI with simulation various knowledge for considering the number of options from N = 3,4, and 5

The results of the velocity v_0 for each multiple-choice question format using our proposed agent model are given in Table 4.5.

In the case of partial knowledge, a random participant might take the outcome beyond the pure guessing strategy. This corresponds to how the options might be reduced to a small number while applying the knowledge. As such, the simulation provided an increase of v_0 in the 3-options format from 0.33 to 0.61, 4-options from 0.25 to 0.49, and 5-options format from 0.2 to 0.41. With the reduction of the number of options N, the success rate v_0 has improved. The results determine the optimal number of options for participants to receive the

TABLE 4.5. Motion in mind measures three multiple-choice question formats between human data and simulation data

Types of Experiments		v_0	m	N	E_0	$\vec{p}$
3-options	Human	0.73	0.27	1.4	0.2878	0.1971
	Simulation	0.61	0.39	1.6	0.2902	0.2379
4-options	Human	0.53	0.47	1.9	0.2640	0.2491
	Simulation	0.49	0.51	2	0.2449	0.2499
5-options	Human	0.33	0.67	3	0.1459	0.2211
	Simulation	0.41	0.59	2.4	0.1984	0.2419

desired outcomes. The human and simulation data results have framed a margin of the average number of options from N=3,4,5 (without knowledge) to $N \in [1.5, 3]$ (partial knowledge) for 3-,4-, and 5-options, respectively.

4.5.2 Challenge-based Gamification and Scaffolding

4.5.2.1 Challenge: Time Pressure

This experiment allows the participants to be reinforced by challenges and changes individual actions toward risk. A challenge mechanics employed in tests indeed creates challenging situations that affect the performance. This study introduced the game mechanics of time pressure as a challenge to capture the positive and negative impact on individual's behavior and performance. Time pressure can change individual behavior and positively and negatively impact students' performance, which senses potential learning and engagement. It is suggested that the effect of time pressure would reduce the disparity between students in the higher and lower groups.

The experimental results were measured by the motion-in-mind model. Table 4.6 provides the quantitative measurement of time pressure inclusion between two groups; 30 minutes group (pre-measure) and 15 minutes group (post-measure). The experiment was conducted for 3-options, 4-options, and 5-options formats. The number of question items was fixed at 30 items. The flow of experiments begins with the pre-measure experiment, which says 30 minutes group, followed by the post-measure experiment, which says 15 minutes group.

TABLE 4.6. Motion in mind measures of three multiple-choice question formats with time pressure from t = 30 to t = 15 minutes

	$time$ **(minutes)**	v_0	m	N	E_0	$\vec{p}$	GR
3-options	30	0.65	0.35	1.5	0.296	0.2264	0.147
	15	0.37	0.63	2.7	0.17	0.232	0.11
4-options	30	0.55	0.45	1.8	0.2736	0.2471	0.136
	15	0.26	0.74	3.9	0.0994	0.1919	0.093
5-options	30	0.36	0.64	2.8	0.1634	0.2293	0.109
	15	0.22	0.78	4.6	0.0735	0.1697	0.085

The difficulty level of question items for both experiments is identical by positioning at a moderate level, but the question stems are different. However, some of the questions might be the same as the previous ones because of the small size of each question item pool. A disparity was found that individual perform better in ample time, while time pressure reduces overall performance. However, the game refinement value of the time pressure group nearly converges to the sophisticated zone of ($GR \in [0.07, 0.08]$), which implies the magnitude of the thrilling sense. The results are summarized as below:

In response to 3-options MCQs, the experimental results indicated the objective velocity v_0 at 0.654 and 0.366, where time t=30 minutes and t=15 minutes, respectively. The objective energy E_0 was 0.296 and 0.169, the momentum was 0.226 and 0.232, and the average number of options N was about 1.5 and 2.7, where time t=30 minutes and t=15 minutes, respectively.

In response to 4-options MCQs, the experimental results indicated the objective velocity v_0 at 0.5535 and 0.259, where time t=30 minutes and t=15 minutes, respectively. The objective energy E_0 was 0.2736 and 0.0994, the momentum was 0.2471 and 0.1919, and the average number of options N was about 1.8 and 3.8, where time t=30 minutes and t=15 minutes, respectively.

In response to 5-options MCQs, the experimental results indicated the objective velocity v_0 at 0.356 and 0.644, where time t=30 minutes and t=15 minutes, respectively. The objective energy E_0 was 0.163 and 0.073, the momentum was 0.229 and 0.170, and the average number of options N was about 2.8 and 4.6, where time t=30 minutes and t=15 minutes, respectively.

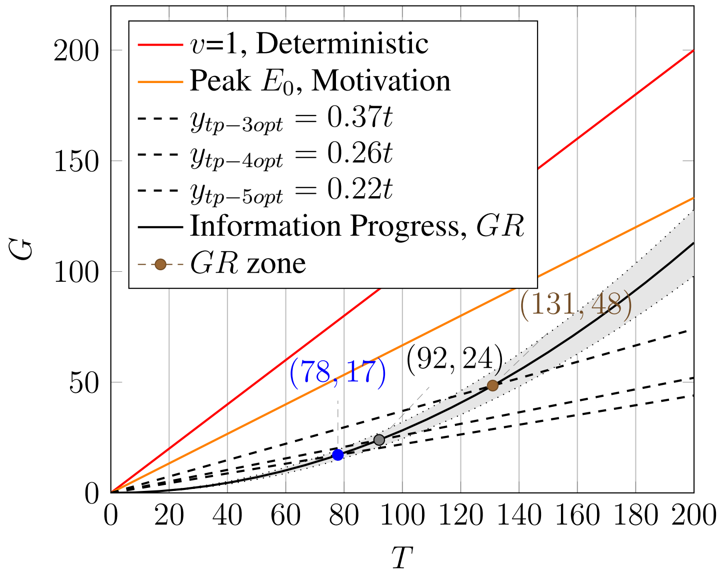


FIGURE 4.4. An illustration of guessing progression with with changes in score (G) and its difficulty (Δv) over total score (T)

Figure ?? depicts score progression with with changes in score (G) and its difficulty (Δv) over total score (T) in each test format applying time pressure. GR values were calculated to investigate the attractiveness of the gamified test. The results obtained from the illustration presents the suitable configuration for the gamified test, which assuming correct response rewards 1 point. The total points/scores in the test would be approximately 131, 92, and 78 for 3-options, 4-options, and 5 options, respectively.

4.5.2.2 Scaffolding

It is hypothesized that effective learning will engage learners in a productive struggle that challenges but does not frustrate them in order to flow in the learning process. One theoretical concept by [176] advocates keeping students in a Zone of Proximal Development (ZPD) by pushing beyond individuals' growth capabilities. [98] proposed the support by hints to keep individual effective learning to struggle with higher challenging tasks. Scaffolding would stretch potential learning beyond the level the participants can do on their own. Its features allow participants to learn to execute these tasks independently and result in the most significant substantial learning gains.

TABLE 4.7. Motion in mind measures three multiple-choice question formats with exclusion and inclusion of scaffolding

		time (minutes)	$No.Questions$	v_0	m	N	E_0	$\vec{p}$
Exclusion	Pre	15	15	0.48	0.53	2.1	0.2414	0.2497
	Post	15	15	0.66	0.34	1.5	0.2963	0.2231
	Total	30	30	0.57	0.43	1.7	0.2806	0.2446
Inclusion	Pre	15	15	0.59	0.41	1.7	0.2859	0.2416
	Post	15	15	0.75	0.25	1.3	0.2802	0.1861
	Total	30	30	0.67	0.33	1.5	0.2962	0.2203

The experimental results were measured by the motion-in-mind model. Table 4.7 provides the quantitative measurement of scaffolding-based experiment between two groups; scaffolding-based with adaptive inclusion (Inc) and scaffolding-based with adaptive exclusion (Exc). The number of question items was fixed at 30. Participants are asked to complete the test separately in 15 minutes for the first part and 15 minutes for the second part (t_1=15, t_2=15, t=t_1+t_2=30). The experiment will distribute five items for 3-options, five for 4-options, and five for 5-options formats in the first half of the adaptive test; the rest will be distributed depending on the performance of the first part. The experiment flow has been inspired by the Computerized Adaptive Test (CAT), which is more suited to execution at the initial stage of studying the topic in order to diagnose the student's initial level of knowledge, and further improvement by presenting tasks of optimal difficulty. There are now three possibilities for creating an algorithm for an adaptive system [177]. The pyramidal approach was used as a criterion, where each student was given a medium-difficulty task. Then, based on the response, the following assignment is generated, the scale of which is lower or higher by two times [178]. This study generalized the adaptive algorithm to be a simpler version by operating moderate-level question items to participants. Evaluation criteria was depending on the performance of the first part; the second part is formed by shifting difficulty, which is easier or harder. For example, the adaptive system would distribute more accessible question items if the performance was below a lower bound. Likewise, the adaptive system will distribute more challenging question items if the performance is above an upper bound. The upper and lower bounds in this study were specified at 75% and 50%, respectively.

When computing the measurement, we see that the inclusion of scaffolding significantly improves knowledge even in challenging tasks, which explains a decrease in N. The adaptive system will provide a practical challenge to the participants to enable the zone of proximal development process. The objective velocity v_0 increased in the second part; also, the velocity was improved if the participants gained knowledge, which observes in the inclusion of scaffolding. The results depict the improvements of velocity v_0 from 0.573 (Exclusion) to 0.672 (Inclusion). In addition, the frequency reward N will reduce from 1.7 (Exclusion) to 1.5 (Inclusion). Interestingly, these effects indicate that inclusion is better for novice-level participants when we assume ability level $k = 3$.

4.5.2.3 Hybrid

Per our hypotheses, learners can maximize their learning potential if we assign a task at the further limits of their ZPD. It might depend on the challenge and support, which affect learning potential and engagement [99]. The properties of challenge-based gamification and scaffolding can sharpen mass m in either increasing or decreasing based on the motion in mind concept. This experiment allows the participants to request and ask for support by hints and keep individual effective learning to struggle with novel difficulties. However, participants were reinforced by time pressure in order to observe the impact in the concurrent situation. The scaffolding would extend potential learning beyond the level, whereas time pressure will maintain the balance between skill and chance as the goal of gamification. The finding allows us to see the impact of both learning and engagement aspects.

TABLE 4.8. Motion in mind measures three multiple-choice question formats with all variations

Types of Experiments		v_0	m	N	E_0	$\vec{p}$
Time Pressure	3-options	0.37	0.63	2.7	0.17	0.232
	4-options	0.26	0.74	3.9	0.0994	0.1919
	5-options	0.22	0.78	4.6	0.0735	0.1697
Scaffolding	Exclusion	0.57	0.43	1.7	0.2806	0.2446
	Inclusion	0.67	0.33	1.5	0.2962	0.2203
Hybrid		0.49	0.51	2	0.2447	0.2499

Table 4.8 provides the experimental data of variation of MCQs by time pressure, scaffolding, and the hybrid system. The results shows a practical cycle of emotion and performance state, in which the mass m will shift between arousal and control zone following the flow theory. This enables the final approximate above the flow zone, which implies optimal arousal. As a result, the hybrid system maintains the scoring rate v_0, which is related to the fairness perspective, which explains a balance between skill and chance. The results depict the refinements of velocity v_0 to 0.49. The objective velocity v_0 aligns at the point where a test taker is required for assistance to tackle more challenging problems. In addition, reward frequency N became 2, which means the participants have to choose between incorrect and correct options. The momentum $\vec{p}$ was 0.249, which implies fairness in the participant performance.Assuming k=3, mass m is located in the boundary between social comfort (m=$\frac{1}{3}$) and play comfort (m=$\frac{2}{3}$), which defines the hybrid system's learning potential.

4.5.3 Variation of Scoring Methods

The proposed experiment aimed to demonstrate that framing effect increases participants' tendency to guess answers in MCQs. We conducted two scoring methods, which are the positive and mixed rules. In all experiments, the dominant strategy was to answer, even without knowledge. This implies that the experiments were conducted under the assumption that the expected score of guessing equals the expected score of omitting. Individuals have some knowledge, and then the probability of choosing the correct answer is greater than $\frac{1}{N}$, and the expected score for guessing will necessarily be greater than 0. If faced with challenging questions, they might choose to omit or guess according to their current conditions.

The traditional scoring rule for multiple-choice questions is the *Number of Right (NR) rule*, in which the test score is simply the number of correct responses multiplied by some constant. The guessing of responses is a prime concern with this rule. There is a probability that a guess will be correct. As a result, test takers can earn points for questions even if they do not even know the answer. For the purpose of analysis, two scoring were conducted to find the impact of the framing effect. The proposed scoring rules in this study are described as below:

- **Mixed Rule:** The scoring rule is that 1 point is given for a correct response, $\frac{1}{N-1}$ points are deducted for each incorrect answer (where N denotes the number of options), and no points are gained or lost for omitting a question.
- **Positive Rule:** It prevents the deduction of points for incorrect responses; 1 point is given for a correct response, $\frac{1}{N}$ points are provided for each omission, and no points are given for an incorrect answer.

Despite such, the two scoring techniques produce different score frames because the Mixed rule includes both gains and losses, whereas the Positive rule only includes gains.

Algorithm 2 MCQ AI with various levels of knowledge in Positive Scoring

```
Result: success rate v0
Input Assign Key Option with 1 point, Distractor with 0 point, question items I
initialization
Sample ← 2400
I ← 300
N ← 3, 4, 5                                                  ▷ *3,4,5 options
TotalPoints ← 0
for x ∈ Sample do
    Sum[x] ←— 0
    for y ∈ I do
        p1 ← random probability ∈ [0.33, 1]                  ▷ *3-options
        p2 ← random probability ∈ [0.25, 1]                  ▷ *4-options
        p3 ← random probability ∈ [0.20, 1]                  ▷ *5-options
        Key Option ← p1, p2, p3
        if p1 or p2 or p3 ≥ 0.33 or 0.25 or 0.20 then
            A[y] ← A Selected Option
            if A[y] contains 1 then
                Sum[x] ← Sum[x] + 1
            else
                Sum[x] ← Sum[x] + 1/N
            end
        else
            Sum[x] ← Sum[x] + 0
        end
    end
    TotalPoints ← TotalPoints + Sum[x]
end
Avg ← TotalPoints / Sample
success rate v0 ← Avg / N
return success rate v0
```

FIGURE 4.5. Algorithm 2: MCQ AI with simulation various knowledge level in a positive scoring rule

Algorithm 3 MCQ AI with various levels of knowledge in Mixed Scoring

Result: success rate v_0
Input Assign Key Option with 1 point, Distractors with -$\frac{1}{N-1}$ point, question items I
initialization
$Sample \leftarrow 2400$
$I \leftarrow 300$
$N \leftarrow 3, 4, 5$ ▷ *3,4,5 options
$TotalPoints \leftarrow 0$
for $x \in Sample$ **do**
  $Sum[x] \longleftarrow 0$
  for $y \in I$ **do**
    $p_1 \leftarrow random\ probability \in [0.33, 1]$ ▷ *3-options
    $p_2 \leftarrow random\ probability \in [0.25, 1]$ ▷ *4-options
    $p_3 \leftarrow random\ probability \in [0.20, 1]$ ▷ *5-options
    $Key\ Option \leftarrow p1, p2, p3$
    if p_1 *or* p_2 *or* $p_3 \geq 0.33$ *or* 0.25 *or* 0.20 **then**
      $A[y] \leftarrow A\ Selected\ Option$
      if $A[y]$ *contains* 1 **then**
        $Sum[x] \leftarrow Sum[x] + 1$
      else
        $Sum[x] \leftarrow Sum[x] + 0$
      end
    else
      $Sum[x] \leftarrow Sum[x] - \frac{1}{N-1}$
    end
  end
  $TotalPoints \leftarrow TotalPoints + Sum[x]$
end
$Avg \leftarrow \frac{TotalPoints}{Sample}$
success rate $v_0 \leftarrow \frac{Avg}{N}$
return success rate v_0

FIGURE 4.6. Algorithm 3: MCQ AI with with simulation various knowledge in a mixed scoring rule

Table 4.9 shows the positive and mixed rules from the experiment with human and simulation data results by running Algorithm 2 and Algorithm 3 (see Figure 4.5 and Figure 4.6). We found that the positive rule provides the best scoring rate v_0, while the mixed rule provides the least success rate v_0. As such, there was a significant difference among scoring methods. Regarding reward frequency v_0=$\frac{1}{N}$, Participants confronted a favorable path in the positive rule because there was no deduction, thus they would evaluate fewer options with the lowest risk. This impacts the number of test options and the guessing effect, which is affected by the individual's risk aversion or seeking desire, because framing effect outcomes can be critical and difficult to eradicate.

TABLE 4.9. Motion in mind measures the variation of scoring methods between human and simulation data

Scoring Methods	3-options				4-options				5-options			
	Human		Simulation		Human		Simulation		Human		Simulation	
	v_0	m	v_0	m	v_0	m	v_0	m	v_0	m	v_0	m
NR	0.73	0.27	0.61	0.39	0.53	0.47	0.49	0.51	0.33	0.67	0.41	0.59
Positive	0.78	0.22	0.65	0.35	0.58	0.42	0.53	0.47	0.4	0.6	0.51	0.49
Mixed	0.66	0.34	0.33	0.67	0.44	0.56	0.37	0.63	0.25	0.75	0.4	0.6

4.6 General Discussion

This study reveals that the number of MCQ options suits the individual at different levels of ability, the influence of different MCQ types by incorporating gamification and scaffolding, and the optimal strategy in the variation of scoring methods. Because the motion-in-mind notion contributed subjective and objective numerical results, the methodology could be improved using human and simulation data to address some of the method's drawbacks. We proceeded by observing and calculating the psychometric properties of our question items. Classical test theory was used to analyze each item's difficulty index and test and compute the discrimination index between high-cognitive and low-cognitive participants. Finally, this research highlighted the validity and reliability using Pearson's correlation coefficient and the Kuder-Richardson 20 Formula ($KR - 20$).

The difficulty index and discriminability are explained by our proposed questions' regarded functional items. Comparisons of the difficulty index in three formats revealed significant variances, with a general tendency for the difficulty of these formats to grow as the number of options increased from 3 to 5. Results indicated that more than 50% of question items are moderate, while most 5-options items are difficult. This support that the larger number of options items were consistently more difficult than the fewer number of options. The change in the number of options appears to affect the overall item performance, suggesting that the number of options in MCQ is a significant factor in influencing test construction. Likewise, the discrimination analysis found no significant difference in overall items; only 19 items were indicated as poor discriminability. The number of options affects the guessing rate whenever the difficulty level of each question is higher than individual ability. These results verify the practicality of our question items, which could be proven by item analysis.

The comparison of concurrent validities based on the TOEIC score found no significant differences between the correlations with the experimental test scores derived from the MCQ. However, there was a higher correlation for the 4-options test than the 3-options and 5-options format since the TOEIC is composed of 4-option multiple-choice items. Also, we ensure internal consistency determined by $KR-20$. There were some significant differences in the $KR-20$ reliability coefficients of the three formats. Primarily, the 5-options format provides the least $KR-20$ reliability, with the coefficients for the format relatively lower and more widely spread due to the lower number of items on which the calculation of the coefficients was founded. These findings aligns with the previous studies [155] and others, that number of options reflects the impact in terms of validity, reliability, and difficulty.

4.6.1 The Optimal Number of Options

This study is to determine the optimal number of options in MCQ and the characteristics of test formats by comparing human and simulation data. We conducted 3-options, 4-options, and 5-options formats starting from the traditional way to variation of MCQ. The finding suggests that the learners' knowledge determines the optimal number of options. Increasing the number of options often lowers the success rate, implying difficulties for the learner. The algorithm produces varied results based on the individual's ability level in each stem due to the random choice options in simulation. There is a distinction between human and simulation data because participants' competence levels may be higher than the benchmark. In practice, when faced with a difficult question, a competent individual will aim to establish the optimal strategy by avoiding guessing in a risky situation with ambiguous information to increase their score margin. This suggests that the outcomes are determined by the process based on the initial individual condition, ability, and risk assessment. This is related to the nature of the motion mind idea, which increases in value in m. This simplifies and deepens understanding of the subjective matter in order to strengthen the concept of motion in mind.

When applying knowledge, the success rate v_0 is significantly shifted in 3-options, 4-option, and 5-options MCQs. Comparison of the findings with those of other studies confirms the impact of variation in the number of options. The small number of options would be a good choice for the beginner level, where 2 options are typically stochastic events where people have a half chance to achieve a correct response. The results confirm that the number of options can increase the task's difficulty, in which the 5-option format is the most difficult MCQ in this study. This result may be explained by the fact that increasing the number of options N to 4 and 5 made the test more difficult as same as the expanding of frequency reward. In contrast, with a decrease in the number of options, the test became easier (fewer options and greater chance rate). These results are in agreement with [44, 161] findings which depicted that fewer options result in a relatively more straightforward test because there is a higher chance of selecting the correct responses. The present results are significant findings that this would be much easier if individuals avoided blind guessing and adopted educated or informed guessing due to their partial knowledge.

The concept of the motion in mind in which the success rate v_0 decreased due to the difficulty increase m. However, it will be effective in the case of a well-prepared MCQ. According to these data, we can infer that the number of options impacts several aspects. In accordance with the present results, previous studies have demonstrated that test takers preferred 3 options for assessment in their entrance examination and performed poorly in 5-option and 6 options due to irrelevant factors such as test anxiety [44]. It could conceivably be hypothesized that individuals generally feel anxious, which increases when encountering such a complex situation. Another possible explanation for this is that 3-options were optimal for test takers, especially at the medium level of ability [66], which underlies the ability level is inversely proportional to the risk rate. It can thus be suggested that 3-options (N=3) contribute evidence that an individual performs such a test and reduce the options to N = 1.5, where E_0 is maximized. This implies that individuals begin in such tests, which are generally easy to try and do not move the individuals' mind; thus, they tend to be highly attractive and provide curiosity, which they are used in most simple quizzes. However, the 3-options format may be optimal depending on the specific purpose, such as a pop-up quiz or a classroom activity.

These results reflect a part of [44] that more options most likely increase the possibility that the test can evaluate additional or actual skills from individuals. The position would be that the optimal number of options depends on the specific testing context, which can be beneficial for assessing individuals or establishing the test. It may be the emphasis that test developers or stakeholders should consider several factors by linking theoretical concepts to consider evaluation impacts when deciding the optimal number of options.

TABLE 4.10. List of standardized tests with the number of options N and types of scoring methods.

Notable Multiple Choice Tests	N	$Scoring\ Method$
TOEIC Listening	3,4	NR
TOEIC Reading	4	NR
TOEFL iBT	4	NR
Scholastic Aptitude Test (SAT) - Before 2017	5	Mixed
Scholastic Aptitude Test (SAT) - After 2017	4	NR
Graduate Record Education (GRE)	5	Negative
Common Law Admission Test (CLAT)	5	Mixed
American College Testing (ACT)	4, 5	NR
Indonesian National Exam	3, 4, 5	NR
Law School Admission Test	5	NR
O-NET (National Examination Test)	4	NR
GAT-PAT (Thailand) - Before 2017	4	NR
GAT-PAT (Thailand) - 2017-Current	5	NR
Japan Language Proficiency Test (JLPT)	4	NR
Test of Proficiency in Korean (TOPIK)	4	NR
Medical College Admission Test	4	NR
National Center Test for University Admissions	5	NR
Driver's License Tests (Japan)	4	NR
Driver's License Tests (Thailand)	4	NR
College Scholastic Ability Test (CSAT)	5	Mixed
Graduate Management Ability Test(GMAT)	5	Mixed

NR = Number-Right Scoring Rule;
Mixed = Mixed Scoring Rule;

In addition, tests taken by students meet the definition of a standardized test, in which everyone takes an identical test, time, under the same circumstances. Such tests are often considered fairer and more objective to remove the flaws. These present findings align with the previous study by [159] that a more considerable number of options per question would increase the content of variability of test results. This is required in high-stakes testing in which they have to be assessed a broad range of subjects and evaluate the competencies of a larger group of candidates. Table 4.10 displays the notable tests in the language proficiency test, license test, or university examination, with the majority still using 4-options and 5-options formats [179]. It is apparent from this table that very few MCQs constructed on fewer options are much less prevalent in the academic environment. With these premises, the 4-options and 5-options are popular in standardized tests, reducing the guessing chance (improves test quality) and reliability by the number of options.

TABLE 4.11. Motion in Mind measures of the notable multiple-choice tests [179]

Notable MCQs	G	T	N	v_0	m	E_0	GR
GAT 1/2013	52.43	150	4	0.35	0.65	0.1589	0.0483
GAT 2/2013	59.26	150	4	0.40	0.60	0.1888	0.0513
GAT 1/2014	49.91	150	4	0.33	0.67	0.1477	0.0471
GAT 2/2014	51.78	150	4	0.35	0.65	0.1561	0.0480
GAT 1/2015	40.39	150	5	0.27	0.73	0.1060	0.0424
GAT 2/2015	45.14	150	5	0.30	0.70	0.1266	0.0448
GAT 1/2016	40.36	150	5	0.27	0.73	0.1058	0.0424
GAT 2/2016	45.34	150	5	0.30	0.70	0.1275	0.0449
GAT 2017	46.35	150	5	0.31	0.69	0.1320	0.0454
GAT 2018	53.63	150	5	0.36	0.64	0.1643	0.0488
GAT 2019	55.09	150	5	0.37	0.63	0.1707	0.0495
GAT 2020	52.43	150	5	0.35	0.65	0.1589	0.0483
GAT 2021	43.64	150	5	0.29	0.71	0.1200	0.0440
Reading TOEIC 2016	262	495	4	0.53	0.47	0.2637	0.0327
Reading TOEIC 2017	261	495	4	0.53	0.47	0.2629	0.0326
Reading TOEIC 2018	259	495	4	0.52	0.48	0.2611	0.0325
Reading TOEIC 2019	265	495	4	0.54	0.46	0.2663	0.0329
Reading TOEIC 2020	323	495	4	0.65	0.35	0.2959	0.0363
Reading TOEIC 2021	279	495	4	0.56	0.44	0.2773	0.0337
Listening TOEIC2016	317	495	3,4	0.64	0.36	0.2950	0.0360
Listening TOEIC2017	320	495	3,4	0.65	0.35	0.2955	0.0361
Listening TOEIC2018	321	495	3,4	0.65	0.35	0.2956	0.0362
Listening TOEIC2019	323	495	3,4	0.65	0.35	0.2959	0.0363
Listening TOEIC2020	337	495	3,4	0.68	0.32	0.2959	0.0371
Listening TOEIC2021	331	495	3,4	0.67	0.33	0.2963	0.0368
SAT 2012	514	800	5	0.64	0.36	0.2952	0.0283
SAT 2013	514	800	5	0.64	0.36	0.2952	0.0283
SAT 2014	513	800	5	0.64	0.36	0.2950	0.0283
SAT 2015	511	800	5	0.64	0.36	0.2948	0.0283
SAT 2016	508	800	5	0.64	0.37	0.2944	0.0282
SAT 2017	527	800	4	0.66	0.34	0.2962	0.0287
SAT 2018	531	800	4	0.66	0.34	0.2963	0.0288
SAT 2019	528	800	4	0.66	0.34	0.2962	0.0287
SAT 2020	523	800	4	0.65	0.35	0.2960	0.0286
SAT 2021	528	800	4	0.66	0.34	0.2962	0.0287

GAT = General Aptitude Test in Thailand;
TOEIC = A standardized language proficiency test;
SAT = Scholastic Aptitude Test;

Table 4.11 compares summary statistics for the test by using motion in mind. A closer inspection of the illustrations shows the values m situating in the range of (0.33,0.5), except for GAT tests. There are changes in the number of options for SAT in 2017 and GAT in 2015. SAT lowers the number of options from 5 to 4, while GAT increases from 4 to 5. This analysis provided empirical evidence that there was no change in SAT since the test is much more predictable in which provides the exact amount of time and number of questions compared with the old version; thus, individuals can prepare themselves and estimate the strategy in the test. Whereas, GAT was opened for applicants only one time after 2017 and there are many tests accounted for in the admission system. Therefore, they want to assess students more accurately in order to effectively screen and not burden them since they would take several examinations in one year. They adjusted to the 5-options format in order to assess the students, and reformat which reflects stability in v_0. However, the quality of the test should be considered since the scoring rate v_0 is very low and it is skill-driven test. It could be stated that GAT test is still need improvements. The most interesting aspect is that GR values are situated under 0.07, except GAT. This implies that these tests are suitable for educational purposes, where curiosity was being and reasonable for education.

Therefore, it could be inferred that competitiveness is characterized by the number of options N, a high number of options regarding difficulty, and an ability level. The only discussion on the differences among the three formats appears to be that the 3-options provide a greater chance of random guessing v_0 and such a learning comfort over 4-options and 5-options. Such a debate may suggest to beginners taking MCQs with more options are better for improving themselves in the sense of competitiveness. The present results are significant in at least two major respects. More options tests are suitable for the learner whose ability level is high, few options may be optimal in such a test with less time, such as a quiz. Further work is required to clarify what might result from implementing changes suggested by quantitative investigations into the optimal number of multiple-choice item options in a given context.

4.6.2 Linking between learning and engagement

The findings suggest that a challenge is an essential element and mechanics in game design, providing a basis for further application in the educational context. Our purpose was to investigate the optimal level of challenge-based gamification in the activity and state the individual's position using both concepts of motion in mind and flow theory to bridge the gap between physics and psychology. The study's findings show the variation in challenge-based gamification by comprising time pressure and difficulty aspects. The results show that challenge-based gamification produced changes in the value m in a more significant way. This implies that complexity or uncertainty can increase competitiveness while increasing subjectivity. Particularly in a conceptual learning environment, an balance between uncertainty and ability is required to emphasize their significance in the education.

The present findings involve the concept of flow theory [25] and zone of proximal development [23], which is a part of the sense of engagement and sociocultural theory of learning. This study investigated how to integrate the scaffolding-based concept in the test. The result showed that scaffolding decreased the changes in value m. This could be described by the motion in mind and zone of proximal development to bridge the gap between physics and learning theory. With respect to motion-in-mind concept, these results show that the ability is shifted from arousal zone to flow zone ($m \leq 0.5$, intuition-driven way) that supports the conjecture of gamified learning theory by [17]. Its transition from challenging zone to control zone indicates learning potential in which combination of two approaches can be used to enhance the learner ability. In an assumption, Vygotsky suggested that it would be best to give students the most challenging tasks they can do with scaffolding as this will lead to tremendous learning gains. It can thus be mentioned that the challenge level must be greater than the ability level, where risk ratio (m) and velocity (v) indicate challenge and ability, respectively. The feasible outcome can assist the potential significance of gamification and scaffolding in the learning and engagement.

This study set out with the aim of capturing the impact of challenge-based gamification in order to improve and enhance engagement and learning-related outcomes in the education context. The effects of time pressure on decision-making under uncertainty were investigated, and the finding depicted the affective state, information process, and task structure in decision-making. His finding is consistent with that of [180] who claimed that time pressure promotes the individual's emotional state. However, the effort was reinforced by integrating different decision-making behaviors to cope with the task conditions. Several reports have shown that time pressure changes individual attitudes toward risk situation [181, 182] and [181].

Prior studies have noted that time pressures benefit students by requiring explicit decision-making, but they also affect decision performance and suboptimal decisions, which restrict the acquisition of new knowledge or strategies [145]. This extends from the finding that individuals respond differently to time pressure when required to handle the situation, as this essential may change the optimal decision strategy.

According to motion in mind, the potential energy value E_0 is mainly situated around m=0.33, which implies the least resistance to informational acquisition. Once time pressure is implemented, students encounter difficult situations that push students to improve their effort and change their behavior. This indicates a sense of curiosity and uncertainty, which affects engagement, and allows for learning-related outcomes. This study supports evidence from previous works [146, 183], in which time pressure induces a student to perform an activity more efficiently and changes how people explore and respond to uncertainty.

The fundamental idea regarding improving learning impact is promoting engagement and the student's emerging potential. Since gamification does not directly improve learning outcomes, the sense of engagement contributing to behavior change has to be improved [16]. Emphasizing the development of engagement contributes to changing behaviors, where such behaviors generally translate into better learning behavior rather than merely considering the activity outcome. Scaffolding is a solution to capitalize on and determine learning-related outcomes. Once a moderate challenge occurs, students may reveal optimum performance with maximum competence to achieve learning-related outcomes. Such a discussion can be observed from the results, the motion in mind values, including v_0, m, and E_0.

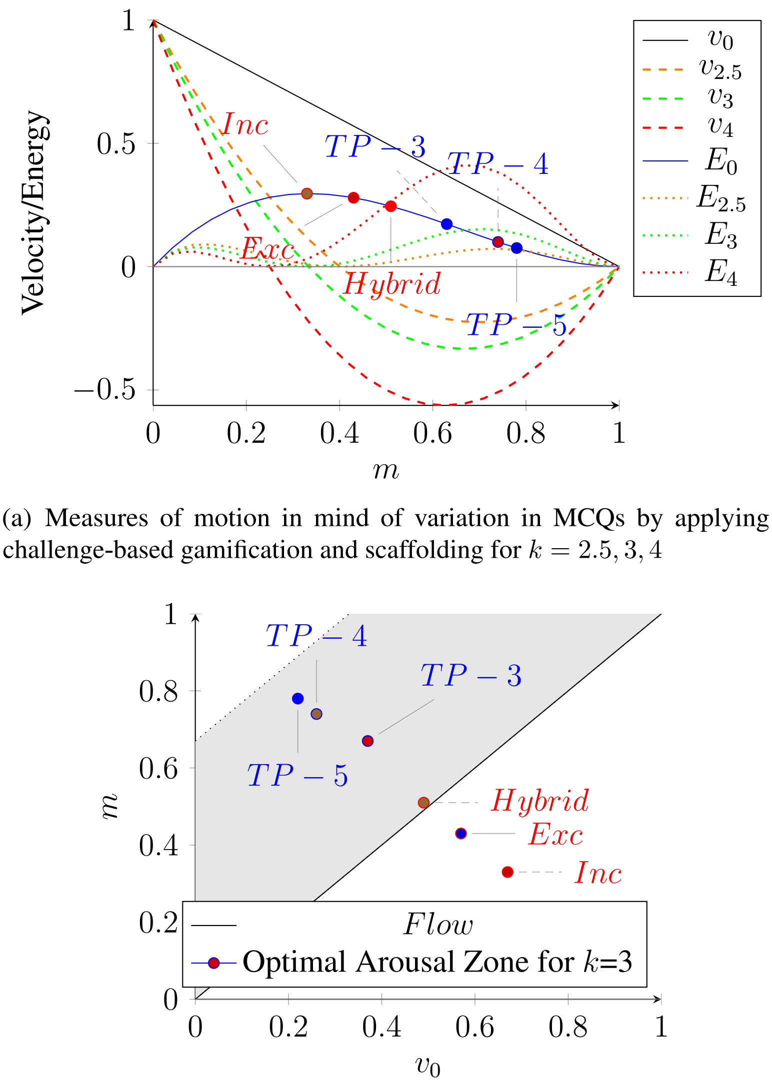
The result of this study verifies the previous conjecture in Chapter 3 that time pressure will provide the intensity of competitive aspects, forcing them to dominate discomfort in the activity [69]. On the other hand, the inclusion of scaffolding by giving hints will improve the success rate v_0. Our findings express the decrease in the number of options that participants will encounter, showing the elimination process when gaining enough information. Since the average number of options in the practical test was around 4 (N=4), the inclusion of scaffolding verifies that it aids participants in solving the challenging questions. Scaffolding improves the value of m by nearly 0.33, which is optimal for novice learners. This situation implies more chance to progress in the test with enabling curiosity (high objective energy E_0).

Once the two approaches were combined, learners experienced that the intensity was reasonable because of the perceived fairness. These consequences show that time pressure and scaffolding about shifted to the flow zone in which individual ability and activity challenge is equal. Learners will be situated in a half-chance scenario, which implies $N = 2$ (where $m = 0.5$). The exploring area with $\frac{1}{k} \leq m \leq \frac{1}{2}$ implies the occurrence of curiosity (encouraged to learn); hence people would explore it. This means Δ_k is maximized, corresponding to the greater scoring rate and stochastic event motion. This implies that the momentum of the test provides the comfort of balance between skill and chance. This region enlarges learner ability so that it is conjectured as a learning comfort at $k = 4$. However, the score may rely on the learner's difficulty and complexity during different occasions, which affects the value m. Learners will gain knowledge by focusing on reinforcers and avoiding mistakes (by using hints). This drives value m to reach the balance between chance and skill, denoted as low competitiveness with fairness and maintaining learning comfort. It can thus be aligned that the present findings support achieving learning and engagement, represented by $1.5 \leq N \leq 2$.

Figure 4.7(a) and 4.7(b) outline the interpretation of challenge-based gamification and scaffolding based on motion-in-mind indicators, namely value v_0, m ,and E_0. Supporting this explanation using the motion in mind, a general discussion could be the possible presence of challenge-based gamification, which affirms the balance of education and entertainment proposed by [17]. This also verify the theory by Vygotsky of the zone of proximal development. The optimal arousal region is denoted as $m \in (0.5, 0.67)$ for k=3. Their potential mechanism can draw the alternative paradigm in the test, directing us to the novel assessment and evaluation method in the education context.

4.6.3 Decision making process under the framing effect

The current study deals with decision-making under subjective uncertainty. Research investigates the impact of framing on MCQs, which refers to the arrangement or approach in which a



(a) Measures of motion in mind of variation in MCQs by applying challenge-based gamification and scaffolding for $k = 2.5, 3, 4$

(b) An illustration between v_0 and m of challenge-based gamification and scaffolding related to the flow concept and the zone of proximal development

FIGURE 4.7. Interpretation of variation MCQs based on motion-in-mind measures

decision maker presents a choice or option. This is necessary in order to select the optimal option from among all potential options depending on the expected outcome, which is explained by gain or loss. While there are several examples of internal ambiguity, little is known about the decision process that drives these decisions. The two scoring methods focused on responses to MCQ as an instance of this decision dilemma. Comparing the two results, it can be detected that there is the highest variance between human and simulation data in the mixed rule. The framing effect may sensitively cause in decision-making due to including gain and loss characteristics. Our proposed experiment is based on an implicit cognitive model of participant behavior in MCQ scenarios under prospect theory. This study underlies the framing effect of the scoring method on an individual's behavior, and we hypothesized that variation in the scoring methods would add the probabilities to represent behavioral changes.

Prospect theory aims to provide a thorough explanation for selecting between objective probability in gambles [184]. The basic principle regards the prospect theory, in which an individual tries to be risk averse. Individuals express differential effects regarding the scoring rules, supported by the results. Theoretically, the common perception is that prospect theory indicates risk-seeking, where individuals perceive loss, while risk-averse, where they perceive gain. It can thus be implied that gain scenarios persuade individuals to be cautious in their decisions if there is a loss on any mistakes. It illustrates that prospect theory can account for choice behavior even when probabilities are not presented. Because practical instances in which the option is explicitly stated are scarce, this theory is vital for interpreting these scenarios.

An initial objective of the experiment was to identify the relationship between the framing effect and the nature of motion-in-mind. The results revealed that participants did satisfactorily in the positive rule and did more flawed in the mixed rule. The scoring rule strongly affects the decision in which the success rate v_0 is varied based on the benefits. As such, the success rate v_0 was more significant in the positive rule than in the mixed rule. The tendency to omit the positive rule is greater than the tendency to guess if the participants have no knowledge. The tendency to guess in the positive rule will be greater than in the mixed rule since there is no loss scenario. Participants will at least omit the question, and assessing their ability from the positive rule is difficult.

However, these results showed that the mixed rule provides a greater of m, which indicates high-stake testing (skill-driven). This can be drawn that this rule is required sufficient skills to overcome the risk. Likewise, this lowers the test's validity and provides some advantages for the particular group with a specific ability. Therefore, most ability tests choose the mixed rule to assess the test takers that satisfy the minimum requirements and desired ability. Although participants may reveal their actual performance in the mixed rule and engage in a gamble in which a loss is a possible outcome. Participants might tend to be risk-averse and have to choose between remaining in the same position with no gain or at least gambling by guessing. It drives participants to guess rather than omit since the remaining position provides less expected value than gambling. Therefore, we found that no standardized tests use the positive rule since the scores may be greater than usual. Generally, Scholastic Aptitude Test (SAT) has applied the scoring rule, subtracting points for incorrect answers. Furthermore, no points are accounted for omitting a question. This allows participants to guess than omit an answer if they have partial knowledge.

A study on behavioral decisions may introduce biases since it aligns with subjective measurement. One majority of mechanics is penalty or penalization, which reduces motivation and inputs more stress. These findings suggest that individuals may demotivate, which indicates an increase of value m and a reduction in E_0. A note of caution is mentioned here that it would be hard to indicate a good performance if the framing effect is becoming robust. This also accords with our earlier observations [106], which stated that it is worth abandoning penalties in conventional tests. It is, therefore, likely that such connections address why the number of rights rule is still popular nowadays.

These results provide support for the promising outcome that the scoring rule impacts individuals in learning and keeping engagement to achieve learning comfort, where $m \leq \frac{1}{k}$, and the learning potential, where $m \leq \frac{2}{k}$.

4.7 Interpretation with respect to Learning Comfort from Motion in Mind Perspective

4.7.1 Mass m Perspectives

Table 4.12 shows various motion-in-mind measures of popular board games and MCQs with 3-options, 4-options, and 5-options, as well as sports games. The table shows a clear trend of GR values in the standardized tests situated below 0.07. In contrast to earlier findings, the experimental results indicated GR values situated in the sophisticated zone ($GR \in [0.07, 0.08]$). There was significant evidence that 4-options MCQ provided fairness while conserving its GR value of nearly 0.05. This implies the feature is the same as in board games where skill is an essential element of play. 4-options MCQs largely depend on a skill that can be made known (or controlled) to influence the test outcome (i.e., the level of knowledge of an individual). It is, therefore, likely that 4- and 5-options MCQs are best practices in standardized tests, and their forms remain consistent when the number of questions or score range increases.

TABLE 4.12. Comparison of various motion-in-mind measures of popular games and sports (adopted from [26]), including MCQs.

Games/Sports/MCQs	G, B	$T.D$	m	E_0	GR	$\vec{p}$	N_{avg}
Chess	35	80	0.78	0.0748	0.0740	0.1709	5
Shogi	80	115	0.65	0.1578	0.0778	0.2268	3
Go	208	250	0.58	0.2021	0.0577	0.2429	2.5
Basketball	36.38	82.01	0.56	0.2190	0.0735	0.2468	2.5
Soccer	2.64	22	0.88	0.0253	0.0739	0.1056	9
3-Options	56.25	77	0.27	0.2878	0.0974	0.1971	1.5
4-Options	89.65	170	0.47	0.2640	0.0557	0.2491	2
5-Options	17.92	53	0.67	0.1459	0.0799	0.2211	3
3-Options*	46.97	77	0.39	0.2902	0.0890	0.2379	1.5
4-Options*	83.3	170	0.51	0.2449	0.0537	0.2499	2
5-Options*	21.73	53	0.59	0.1984	0.0880	0.2419	2.5
GAT 2020	52.43	150	0.65	0.1589	0.0483	0.2274	3
GAT 2021	43.64	150	0.71	0.1200	0.0440	0.2063	3
Listening TOEIC2020	337	495	0.32	0.2959	0.0371	0.2173	1.5
Listening TOEIC2021	331	495	0.33	0.2963	0.0368	0.2215	1.5
Reading TOEIC2020	282	495	0.43	0.2793	0.0339	0.2451	2
Reading TOEIC2021	279	495	0.44	0.2773	0.0337	0.2460	2
SAT 2020	523	800	0.35	0.2960	0.0286	0.2264	1.5
SAT 2021	528	800	0.34	0.2962	0.0287	0.2244	1.5

According to these data, we can infer based on four parameters;E_k, Δ_k, v_k, and δ_k. To determine the learning comfort from mass m, subjective energy E_k was applied to demonstrate motivation for various individuals' ability levels (defined as curiosity). As the objective measures, participants were found to struggle with test potential that quantifies by objective energy E_0. Another important finding was that extrinsic and intrinsic motivation differences can be defined in this context by calculating the difference between objectivity and subjectivity, which is E_0-E_k or defining as the reinforcement difference Δ_k. It would be optimized by specifying two peaks when the success rate v_0 is ranged between the maximum threshold of objective reinforcement E_0 at v_0=0.67 (or m=0.33), where reinforcement difference Δ_k

will be maximized, and the subjective reinforcement E_k at $v_0 = \frac{k-2}{k}$, where Δ_k will be zero. The learning comfort holds the objective reinforcement E_0 dominating over the subjective one E_k, where Δ_k is maximized at peak E_0. This verifies the region where learning comfort was identified, with a strong objective reinforcement and curiosity at $\frac{1}{k} \leq m \leq 0.5$. Potential energy E_0 reduces, which reflects inhibiting reinforcement. Participants noticed that the test would be challenging to accomplish desired outcomes. Reinforcement difference Δ_k nearly becomes 0, which satisfies the harmonic balance between objectivity and subjectivity at E_0=E_k. This point is denoted as the learning potential.

A minor degree of uncertainty provides assurance in repeating the action, making it appealing but stochastic. This scenario is analogous to the game design principle of accessible to learn but difficult to master [185]. This promotes the momentum of test δ_k becoming bigger and lower than v_k. Regarding the competitive zone where such tests move an individual's mind, the momentum of test δ_k becomes smaller. This region possesses a challenge equivalent to the player's ability. In a sense, this underlines the level of knowledge an individual must attain to overcome challenging tasks. This can be seen by negative peak v_k and peak E_k, which are denoted as optimal arousal point and competitive zone, respectively.

Table 4.13 and 4.14 depict the analogical interpretation of value m compared to game context and implication in the educational context based on the motion in mind concept.

TABLE 4.13. The analogical interpretation of value m compare to game context

m	**Indication**	**Game context**	**Educational context (MCQ)**
0	v_0=1	Deterministic	Mastery
0.33	Peak E_0	Objective Motivation	Learning Comfort
$\frac{1}{k}$	v_k=0, E_k=0	High Reinforcement	Curiosity (Encourage to learn)
0.5	Peak δ_k	Fairness, Low Competitiveness	Balance between ability and chance
$\frac{2}{k}$	E_0=E_k	Mass Entertainment, Play Comfort	Learning Potential
$\frac{1+k}{2k}$	Negative peak v_k	Perceptive Turnover, Gamified	Flow to Optimal Arousal
$\frac{N-1}{N}$	$v = \frac{1}{N}$	Equiprobability	Uncertainty among N options (Guessing)

TABLE 4.14. Implication of scoring difficulty m^* in the educational context based on motion in mind concept

Range	m*	Implication
E_k=0, max Δ_k	$\frac{1}{k}$	Learning Comfort
max δ_k	0.5	Fairness
E_0=E_k	$\frac{2}{k}$	Learning Potential
max E_k	$\frac{\sqrt{9(k^2+1)-2k}+3(k+1)}{10k}$	Competitive

By motion in mind theory, the interpretation of m with respect to learning comfort was addressed. It has a piece of evidence that the 4-options format characterizes fairness properties, among others. In contrast, the 3-options format implies simplicity as owning non-competitiveness, which is suitable for an individual with a low ability to drive their effort at the maximum level of motivation. The 5-options format was the most difficult due to competitiveness, which is required for individuals with high abilities. This study concludes that 4-options and 5-options are the assessment through which challenge-based gamification can moderate gamified and competitive experiences and produce a learning-related behavior [186]. In light of the statement, the results reveal that it is entirely rational for most standardized tests usually attempted on the 4-options and 5-options format.

4.7.2 Reward Frequency N Perspectives

In the current findings, simulation data from various ability levels of individuals by indicating $N = 3, 4, 5$ provided risk chance m was situated at 0.39 (3-options), 0.51 (4-options), and 0.59 (5-options), respectively. This reflects that three test formats are promising for learning since the reinforcement differences are optimized in the range. The analogical studies of popular board games and the evolution of multiple-choice questions analyzed these results. 4-options and 5-options require skillful participants to overcome, which explains changes in ability level k. This result states the potential of an optimal number of options in the popular tests. The effect of the number of options is related to the variable ratio (VR) described in the motion-in-mind concept. Sophisticated board games such as Go, Shogi, and Chess have distinct values of N and represent different aspects [32]. Go is aligned N=$\frac{5}{3}$ at m=0.4, in which the reward frequency is high and requires the low ability to move the game. Shogi would relate to a situation that induces high curiosity (motivated effort) to mass entertainment since N=3. The region beyond this area, like Chess (N=5), requires the ability and effort to push the game. Such a region implies competitiveness, which is often motivated. However, sports games provide N in the competitive region, which implies a chance game.

4.7.3 Interpretation on Educational Assessements

Table 4.15, 4.16, and 4.17 show various motion-in-mind measures of popular standardized MCQ tests by assuming ability level at $k = 3$. The trend of the evolution changes in the number of option N and scoring rules reveal the differences in motion-in-mind values. This study observed and investigated the interpretations of these three standardized tests based on motion-in-mind perspectives. From the data collection, GAT increased the number of options from 4 to 5 options in 2015. Increasing the number of options in the GAT signifies a more difficult test, which indicates a skill-driven test. Furthermore, they reduced the number of tests, in 2017, to only one time per year, which must provide simpler tests to use in practice. That is the reason why the m value was reduced.

Meanwhile, Table 4.16 shows no significant change in SAT even though they reduced the number of options to 4 in 2017. However, SAT provides the highest Δ_k, which shows the learning comfort characterizes this test where curiosity emerges ($m = \frac{1}{k}$). SAT is becoming improved

Lastly, TOEIC Test has significantly improved to simplify the test for every test taker, as shown in Table 4.17. Its balance simultaneously provides learning comfort and a learning process at the same time, where the m value is nearly around 0.33 (the listening section) and 0.5 (the reading section). The number of options has never changed, as they remain 4 options for the reading section and 3- and 4-options for the listening section. TOEIC tests provide the balance between ability and chance, where δ_k is maximized.

TABLE 4.15. Motion in mind measures for GAT tests from 2013 to 2021 with $k = 3$

Notable Tests	N	v_0	m	v_k	δ_k	E_0	E_k	Δ_k
GAT 2013/1	4	0.35	0.65	-0.333	0.682	0.1589	0.1439	0.0151
GAT 2013/2	4	0.40	0.60	-0.322	0.717	0.1888	0.1254	0.0635
GAT 2014/1	4	0.33	0.67	-0.333	0.666	0.1477	0.1483	-0.0005
GAT 2014/2	4	0.35	0.65	-0.333	0.678	0.1561	0.1451	0.0109
GAT 2015/1	5	0.27	0.73	-0.321	0.590	0.1060	0.1506	-0.0446
GAT 2015/2	5	0.30	0.70	-0.330	0.631	0.1266	0.1524	-0.0258
GAT 2016/1	5	0.27	0.73	-0.321	0.590	0.1058	0.1506	-0.0447
GAT 2016/2	5	0.30	0.70	-0.330	0.633	0.1275	0.1524	-0.0249
GAT 2017	5	0.31	0.69	-0.332	0.641	0.1320	0.1519	-0.0200
GAT 2018	5	0.36	0.64	-0.332	0.689	0.1643	0.1413	0.0230
GAT 2019	5	0.37	0.63	-0.330	0.697	0.1707	0.1377	0.0330
GAT 2020	5	0.35	0.65	-0.333	0.682	0.1589	0.1439	0.0151
GAT 2021	5	0.29	0.71	-0.328	0.619	0.1200	0.1525	-0.0325

TABLE 4.16. Motion in mind measures for SAT tests from 2012 to 2021 with $k = 3$

Notable Tests	N	v_0	m	v_k	δ_k	E_0	E_k	Δ_k
SAT 2012	5	0.64	0.36	-0.047	0.689	0.2952	0.0016	0.2936
SAT 2013	5	0.64	0.36	-0.047	0.689	0.2952	0.0016	0.2936
SAT 2014	5	0.64	0.36	-0.049	0.690	0.2950	0.0017	0.2933
SAT 2015	5	0.64	0.36	-0.053	0.692	0.2948	0.0021	0.2927
SAT 2016	5	0.64	0.37	-0.060	0.695	0.2944	0.0027	0.2917
SAT 2017	4	0.66	0.34	-0.016	0.674	0.2962	0.0002	0.2960
SAT 2018	4	0.66	0.34	-0.006	0.670	0.2963	0.0000	0.2963
SAT 2019	4	0.66	0.34	-0.013	0.673	0.2962	0.0001	0.2961
SAT 2020	4	0.65	0.35	-0.025	0.679	0.2960	0.0004	0.2955
SAT 2021	4	0.66	0.34	-0.013	0.673	0.2962	0.0001	0.2961

TABLE 4.17. Motion in mind measures for TOEIC tests from 2013 to 2021 with $k = 3$

Notable Tests	N	v_0	m	v_k	δ_k	E_0	E_k	Δ_k
Reading TOEIC2016	4	0.53	0.47	-0.412	0.747	0.2637	0.0448	0.2189
Reading TOEIC2017	4	0.53	0.47	-0.418	0.748	0.2629	0.0460	0.2169
Reading TOEIC2018	4	0.52	0.48	-0.430	0.748	0.2611	0.0483	0.2127
Reading TOEIC2019	4	0.54	0.46	-0.394	0.746	0.2663	0.0413	0.2250
Reading TOEIC2020	4	0.57	0.43	-0.291	0.735	0.2793	0.0236	0.2557
Reading TOEIC2021	4	0.56	0.44	-0.309	0.738	0.2773	0.0265	0.2508
Listening TOEIC2016	3,4	0.64	0.36	-0.079	0.691	0.2950	0.0018	0.2931
Listening TOEIC2017	3,4	0.65	0.35	-0.061	0.686	0.2955	0.0011	0.2944
Listening TOEIC2018	3,4	0.65	0.35	-0.055	0.684	0.2956	0.0009	0.2948
Listening TOEIC2019	3,4	0.65	0.35	-0.042	0.680	0.2959	0.0005	0.2954
Listening TOEIC2020	3,4	0.68	0.32	0.042	0.652	0.2959	0.0005	0.2954
Listening TOEIC2021	3,4	0.67	0.33	0.006	0.665	0.2963	0.0000	0.2963

4.8 Practical Implications

This study incorporates the theoretical concept for analyzing the learning process employed in educational assessments. The game design elements and adjustment in an educational setting motivate individuals and effectively achieve learning objectives. Consolidating these concepts through the educational assessment is beneficial in providing a positive effect. To understand how to develop an optimal system that may encourage and improve intrinsic motivation, it should separate game elements and analyze their usefulness in the learning process. This study investigated the relationship between four key terms in the learning process: learning comfort, learning process, learning potential, and learning outcome (shown in Figure 4.8).

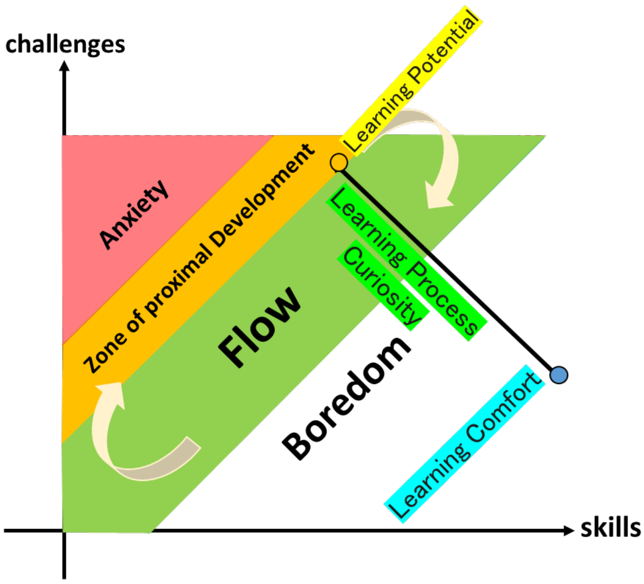


FIGURE 4.8. A conceptual scheme Learning Outcomes through Learning Comfort, Process, and Potential

A conceptual scheme for analyzing the learning process is illustrated in Figure 4.9. The interrelationship between learning comfort and learning potential is addressed in the different outcomes of the positive effect. Positive effects provide behavioral change and individual performance. Once motivation and curiosity are activated, individuals will be situated in learning comfort where engagement strengthens. These consequences will trigger the learning process, implying the ability improvements based on the points and score measurement.

Gamified elements and reinforcement caused this phenomenon. The scaffolding approach maintained the balance between challenge and ability in order to keep the engagement level. Engagement would fade if all learning environments were gamified, and an input challenge was beyond learning potential.

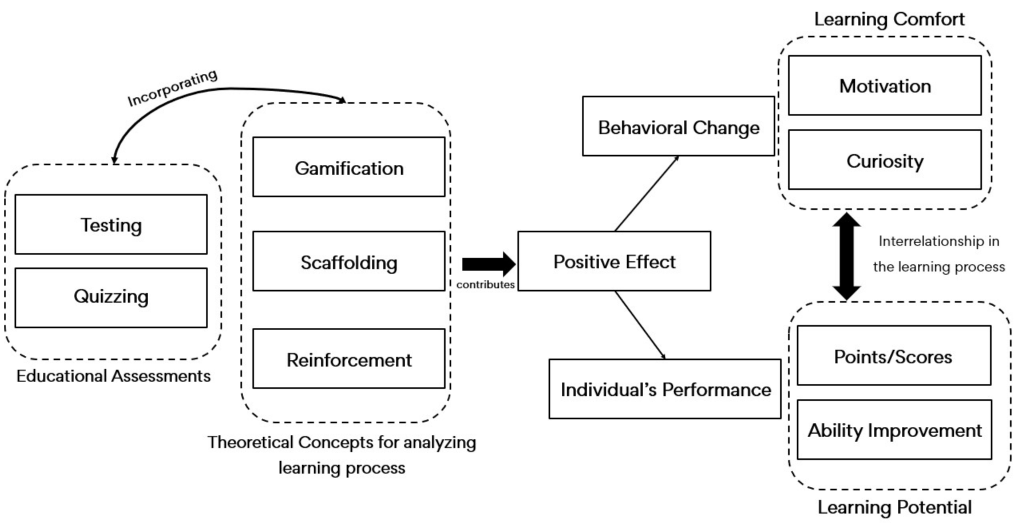


FIGURE 4.9. A conceptual scheme of analyzing the learning process.

This combination of findings supports the conceptual framework that 4-options tests highlight an ideal measurement that balances chance and ability. Figure 4.10 compares various motion-in-mind measures of variation MCQs. The number of rights is ubiquitous for employing in the tests, and the least competitiveness was determined in the number of right rules where δ_k is nearly maximized. This verifies that most standardized tests technically employ the 4-options format, including the English proficiency tests and national tests at the high school level.

Meanwhile, potential energy E_0 is maximized in the scaffolding-based test. It would be better if beginners attempted to learn the contents of the test. Individuals may learn from what they know nothing about until they achieve the potential learning. With this conjecture, this study reassures that scaffolding is a good option for learning and developing their ability while playing, as shown in [24, 187]. This affirms that scaffolding can yield potential development based on the notion of ZPD. A proposed hybrid system supports the findings in [99] that

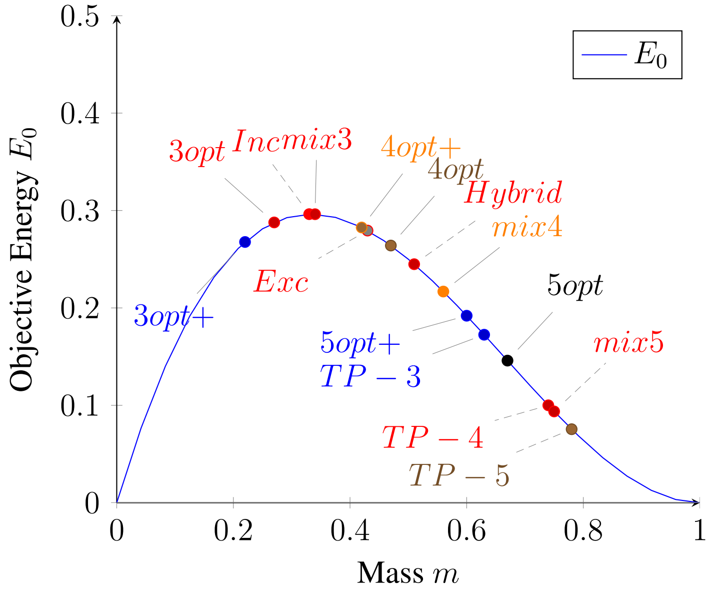


FIGURE 4.10. Comparison of variation in MCQs based on motion in mind measures, E_0

simultaneously included time pressure and scaffolding, indicating that m value was improved until relatively fair $m = 0.5$. The reward frequency between individuals and options is stochastic. The ability difference evolves larger than in other systems. This framework finely highlights the aspects that individuals would feel learning comfort due to its fair properties and versatility for every people compared to other tests.

According to the scoring methods, A decision maker tends to be risk-averse or risk-seeking depending on how the minimum expected outcome is represented in terms of risk chance and knowledge. In general, decision-makers are risk averse when faced with positively framed difficulties [108] and risk-seeking when faced with negatively framed challenges and reinforcements. The results depicted that the mixed rule provided the most unsatisfactory outcome compared to each other. The 5-options format with mixed rule contains the highest competitiveness (low δ_k), while the least competitiveness δ_k in the 3-options. This implies that the mixed rule might be suitable to apply in the lower number of options N in order to satisfy the learning comfort. The loss exploits larger when the number of options N increases since the risk chance m will become stronger. In this case, 3-options mixed rule is a reasonable alternative for producing learning comfort: beginners can take a test and learn at their own pace while maintaining engagement and high motivation. The 5-options mixed rule requires high skill to keep motivation since the test will be challenging to achieve. It implies the competitive zone where an individual's performance level should be robust.

4.9 Chapter Summary

This study investigated the effect of the number of options in multiple-choice questions using analysis of motion-in-mind theory to link theoretical approaches, including gamification, scaffolding, and prospect theory, by variation of test elements and scoring methods. The current study's findings suggest that increasing the number of options N makes the test more challenging, followed by increasing the m value. The results from the current study indicate the changes in the success rate v_0, which reflects suitable ability level k on taking our question items.

The hypothesis was that a moderate level of challenge, slightly exceeding an individual's ability, would enhance the learning process and improve their learning potential. The results indicated that a comfortable learning environment, characterized by a balance between challenge and reinforcement, can lead to greater engagement and motivation, ultimately resulting in better learning outcomes. However, a lack of challenge or learning comfort can limit the individual's potential and hinder the learning process. It is crucial to consider other factors such as task difficulty and motivation in determining the scoring rate.

This study has provided a deeper insight into the variation of MCQs by interpreting m according to the motion-in-mind concept. The proposed system improved the learning environment to reduce frustration and develop a genuine learning process. This implies the presence of a learning process under a control state where the challenge was adequate. A lower m value allows individuals to improve their learning without extrinsic motivation, as described by the increases in velocity v. The zone of proximal development was found, where individuals are scaffolded to do tasks beyond their ability, and they will learn to do tasks independently. Also, this study has extended our knowledge of the framing effect in the scoring methods. It yields the generality of prospect theory in which individuals tend to answer under uncertainty when the gain is obtained. The number of rights and the mixed rule is worth considering in educational assessment. The framing effect is anticipated to contribute to our understanding and insight into educational and standardized tests.

The most important limitation is that our proposed experiment may require a more profound analysis that works in different circumstances and considers further factors. The proposed algorithm might be improved to cope with different participants with partial knowledge. Secondly, although the internal validity and reliability were verified by classical test theory, external validity could not be achieved due to the small sample size of question items and participants for comparison with other practical cases. Hence, these results may be inconsistent with other conceptual schemes. As such, this limitation suggests caution when interpreting the results since such findings were not externally validated, requiring further investigation.

Regardless of the number of options and context, our findings can be an extension study for analyzing the balance between competitiveness and entertainment while seeking the learning process in the educational context. These findings enable scholars to improve educational assessment to increase stakeholders' motivation and engagement while also challenging and entertaining them. Future studies should also consider complex details when designing the test in educational settings.

CHAPTER 5

Conclusion

This dissertation incorporates game elements that promote and enables the learning process by which considering from a learning comfort and engagement point of view. This dissertation has identified the individual's perceived impact and learning process on the educational assessment by using the analysis from motion-in-mind perspectives. Our proposed game progress model and motion-in-mind measures in this dissertation consolidated theoretical concepts to provide essential insight for bridging the gap between game and non-game contexts, including an education context.

The first part of the dissertation (Chapter 3) focuses on integrating challenge-based gamification into an elementary school classroom to capture the emergence of student engagement and learning-related outcomes. The mixed methods design experiment was built on time pressures and the difficulties of game elements in the quizzing. The experiment was developed to investigate behavioral results by using Kahoot! The time pressure element was first applied in the experiment by altering the time for each question. The difficulty was then modified based on predetermined parameters, and the pattern adaptation was carried out. The quantitative analysis was carried out using the parameters of the motion-in-mind concept and game refinement theory, while the qualitative part aimed to understand better gamification's impact on individuals' experiences and motivations by interviewing. The findings suggest that a challenge is an essential element and mechanic in game design, providing a basis for further application in the educational context and the variation in challenge-based gamification positively contributed to the motivational outcomes, which enables the learning process. Game mechanics can make games more interesting as a method for analyzing and capturing impact. As a result, classroom activities might be gamified for individuals to fully comprehend the efficacy of interactive tools. To achieve the learning-related outcomes, challenge-based gamification should be addressed, which provides individuals to keep motivated and learn.

The second part of the dissertation (Chapter 4) focuses on the variation of the educational assessment (MCQs). The relationship between an education context and theoretical concepts was analyzed to determine the learning process and outcome that occurs during the educational assessment experience. The underlying principles of challenge-based gamification, zone of proximal development, and prospect theory were developed to examine insights into educational assessment through the motion-in-mind perspective. The contribution has been to revisit the notion of learning comfort, primarily because this study connects the reinforcement and curiosity interpretation with servicing the education context. The analysis proceeded to investigate the number of options, incorporating challenge-based gamification and scaffolding, and scoring methods in the context of MCQs. Research findings also address the general discussion, which helps link analogical interpretation in the education context. This collection of findings gives credence to the conceptual framework that highlights an ideal measurement that provides a balance of chance and skill, as well as the aspects that individuals would feel learning comfort due to its competence.

Finally, the conceptual framework and analogical interpretations have led to the relationship between learning comfort and learning engagement. This outcome contributes to existing knowledge of proposed theoretical concepts, which is closely tied to the learning process. This new understanding promisingly improves the enhancement that impacts the learning process and aligns perceptions of learning comfort and learning engagement within the educational assessment.

5.1 Learning Comfort and Engagement within the Educational Assessment

To generalize the learning process, we conjectured our understanding from two aspects: learning comfort and learning engagement. Adjusting the number of options in multiple-choice questions is proposed to improve the guessing rate, which hinders the learning process, focusing on the number of options and scoring rate (or success rate) over the other individual performance. Gamification and scaffolding verify that gamified experience and guidance impact performance and learning strategies. Likewise, the investigation on scoring methods affects the decision-making process, which is essential to define the optimal strategy under uncertainty like MCQs. Understanding the reward frequency N, risk frequency ratio m, and motivation E_0 are essential to identify the optimal number of options and learning comfort. Since the value of N can be regarded as the measure of the number of options, it serves as an indicator to determine the border between learning and competitive aspects. Hence, analysis of the changes of N provides insights into MCQ terminology and captures its subjective interpretation concerning m value. This study justifies the interpretation based on adoption from [26, 32].

5.2 Addressing the Research Questions

This dissertation has revealed several findings with the following objectives: (1) To capture the impact of the variation in challenge-based gamification using the gamified platform, (2) To define the learning comfort via theoretical approaches based on the MCQs testbed, and (3) To identify the link between learning and play by proposing a new measurement of motion in mind perspective.

The answer to the first question was obtained by incorporating challenge-based gamification in the gamified platform to capture the impact of challenge-based elements in the quizzing and represent the notion of engagement and learning in the sense of motion-in-mind. Challenge-based gamification confirms the contribution to the learning aspect and induces a specific outcome. According to flow theory, the challenge causes students' experiences to transition into an arousal zone, which evolves if the challenge and students' skills are encouraged. The results support that motivation increases once the challenge is applied until it reaches the individual's capability. The impact of v and m in the transition process of flow is generalized from the experimental results. An extensive analysis related to the motion-in-mind concept shows that time pressure, difficulty, and adaptation promote risk-taking m. Individuals may perceive learning engagement when $m \geq v$ and perceive learning comfort $m \leq v$. An understanding of the balance between educational value and entertainment was mentioned, which can be approximated at $m \leq 0.5$, where learners feel under control when the challenge is appropriate. The proposed mixed methodology approach suggests that it promotes the motivation to learn and to do tasks and efficiency of quizzing in short-term. To promote long-term success, however, more than one game element must be included, or game mechanics must be modified. Thus, the ideal learning conditioning occurs when game elements and well-designed processes are incorporated.

The results from research question 1 is used to generalize the harmony between learning and engagement. The research question 2 and 3 focuses on the extent to which an educational assessment encourages the learning process, as well as the learning process aspects that may occur objectively and subjectively during an educational assessment. The findings of the study provide a foundation for further application in the educational environment. To highlight the relevance of uncertainty and capability, a balance between them is essential, especially in the learning process. The second and third objectives are closely related to one another. The most obvious finding in Chapter 4 has extended our knowledge of motion-in-mind that provides the novel comprehensive emergence of curiosity. This findings has raised important interpretation on learning comfort in the physics-in-mind perspectives. As explained earlier, learning comfort holds the objective reinforcement E_0 dominating over the subjective one. This study has identified that individuals acquire knowledge in the learning process, and the number of plausible options would be specified by lowering the options N and m values. The success rate v_0 was more significant, which means individuals can be engaged to learn in the learning comfort, where $m \leq \frac{1}{k}$. Δ_k is maximized at peak E_0. This confirms the placement of learning comfort, with a significant reinforcement and curiosity at $\frac{1}{k} \leq m \leq \frac{1}{2}$. The existing data clearly support the relevance of learning comfort, which demonstrate that the differences among the three formats of MCQs.

5.3 Concluding Remarks

The findings presented in this dissertation has provided and revealed key insight for bridging the gap between game and non-game environments. One of the keys to enhancing motivation and learning abilities is determining and optimizing for practical assessment. With our proposed measures, this dissertation ensures the conjecture between learning comfort and playing comfort based on the objective point of view. The value of m by nearly 0.33 indicates the optimal condition for novice learners, where the chance to progress in the test contains high curiosity (high objective energy E_0). This dissertation verifies an optimal way to expand our understanding of how the learning process emerges during the transition from learning engagement to learning comfort. Findings indicate that our proposed analysis with theoretical approaches particularly provides an effective learning into three different viewpoints as below.

- The success rate v_0 is significantly shifted in 3-options, 4-option, and 5-options MCQs when applying knowledge. The differences among the three formats appear that the 3-options provide a greater chance of random guessing v_0 (peak E_0) and such a learning comfort over 4-options (peak δ_k) and learning engagement 5-options ($E_0 = E_k$) where $k = 3$. The simulation results has shown the approximated m that three test formats are promising for learning since the reinforcement differences are optimized in the range $m \in [0.3, 0.6]$ and $N \in [1.5, 3]$. If individual's ability is varied, the subjective values will be shifted either increasing or decreasing.
- A hybrid system, including time pressure and scaffolding, provided relatively fair conditions at the value of $m = 0.5$. The learning comfort zone with $\frac{1}{k} \leq m \leq \frac{1}{2}$ implies the occurrence of curiosity (encouraged to learn). Otherwise, it becomes a more competitive and more gamified experiences which requires skill to achieve the test (a decrease in δ_k). Gamified elements and scaffolding elements are incorporated to improve the learning process, as same as the transition of m value where learning

comfort are maintained. This aligns with the support that the educational context can achieve learning and engagement, represented by $1.5 \leq N \leq 2$.

- The number of rights and the mixed rule are worthwhile to consider applying in educational assessment. Regarding reward frequency N, the impact of framing on MCQs reveals the mixed rule appeared more obvious than the positive rule. The scoring rule has a significant impact on the decision, as the success rate v_0 was higher in the positive rule than in the mixed rule. However, the mixed rule provide greater of m, which requires skill to overcome the risks. The scoring rule impacts individual in learning and keeping engagement to achieve the learning comfort, as observed in both human and simulation data, which indicates as an increase of value m and a reduction in E_0.

5.4 Future Recommendations

A further study could assess the long-term effects of quizzing and the educational assessment to observe the different notions of learning comfort in the region of $N \leq 1.5$, which might clearly interpret value m in the education context. Further investigation and experimentation toward the practical MCQs is strongly recommended in order to improve the standardized test and efficiently adopt in the specific context.

More broadly, research is also needed to explore towards the use of a dynamic approach, including the artificial intelligence that can cope with diverse participants. Furthermore, while incorporating engaging gamified quiz or test in educational settings, future directions should address sophisticated aspects. The precise mechanism of gamification and scaffolding in MCQs remains to be elucidated. More systematic study might be useful to provide more definitive evidence on motion-in-mind perspectives. This dissertation is the application of theory in practice with the learning-related outcome that have been designed to be used a practical test. It is anticipated that educators will be used in the test design process to better facilitate fair, equitable, norm-referenced assessment.

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Appendix A

This appendix contains interview questions used in the qualitative analysis in Chapter 3. Also, it provides a collection of TOEIC questions used in Chapter 4.

1. Interview Question used in Chapter 3

(1) What do you think are the significant impacts of the three different challenge-based approaches on gamified quizzing?
   (a) How was your motivation/engagement?
   (b) How was your learning achievement?

(2) What did you feel about your involvement during the time pressure gamified experience?

(3) What did you feel about your involvement with the variation in the quizzes' difficulty?

(4) What did you feel about your involvement during the adaptation of quizzing (subgoal and random difficulty)?

(5) Which kind of gamified quizzing did you prefer?

(6) What benefits did you obtain from challenge-based gamification?

2. A Collection of TOEIC Questions from several sources used in Chapter 4

TABLE 5.1. List of Questions used in Chapter 4

No.	Questions
1	The document that you requested _ on your desk.
2	The _ businessperson always dresses appropriately.

Table 5.1 continued from previous page

No.	Questions
3	You will find all the pencils you need _ that drawer.
4	Several important pieces of information were _ from the report
5	If the weather is bad, we _ the trip.
6	You can always count on Ms.Cho, as she is one of our most _ employees.
7	Mr.Jones finally _ a promotion, and he was very happy to get it.
8	The office was in excellent condition when we moved in because the former _ was very tidy.
9	No one can go home _ the work is finished.
10	Just walk _ that door and you will see the copy machine on the other side.
11	There were several qualified candidates for the job, but we could _ only one.
12	In order to be _ to the building, you must show proper identification.
13	There's a phone on the table _ my desk.
14	It is a bit scary riding this elevator because it _ at such a rapid rate.
15	_ your time card whenever tou enter or leave the building.
16	When payday _ , all employees will received their checks in the mail.
17	Ms. Wilson was fired _ she always arrived late and never finished her work on time.
18	Our boss is very organized and tidy and _ that we keep the office near.
19	_ Mr. Lee works very hard and always meets his deadlines, he still hasn't been given a promotion.
20	He _ an employee of this company ever since he first started working.

Table 5.1 continued from previous page

No.	Questions
21	The walls are in bad shpae and will require _ before we can begin paiting them.
22	If we _ all night, we might have finished the report on time.
23	It is necessary to have at least one advanced degree in order to _ in today's job market.
24	Because so few people showed for the meeting, we decided to postpone it to a later date.
25	The office is right _ the street from the subway station.
26	If you wish to speak with the director, you should _ an appointment first.
27	The _ of our products is well known throughout the world.
28	All employees are expected _ at the office on time every day.
29	All expenses must be approved _ the department head at the beginning of each month.
30	The meeting will take place tomorrow from 10:00 _ 11:00.
31	We _ finish this work soon because the deadline is approaching.
32	This _ is very important, so think it over carefully.
33	_ off the lights before you leave the office.
34	The new rug looks very nice _ that table.
35	The books that he recommended _ not very interesting.
36	Mr. Kim is not a particularly interesting speaker, and several people fell asleep _ his lecture.
37	Our business is rapidly _ and we are hiring many new people.

Table 5.1 continued from previous page

No.	Questions
38	The building _ during the heavy thunderstorm last night.
39	People who have no _ are seldom disappointed.
40	Please don't ask for personal information about our employees, as we keep that information _.
41	Mr. Jones _ investing in that company, but he finally decided against it.
42	If we hadn't left the house so late, we _ the plane.
43	There reports must be turned _ before the end of the week.
44	Samantha worked very hard and put in a lot of overtime hours because she hoped for an _ in her salary
45	They brought extra chairs into the room _ they expected a large number of people to attent the meeting.
46	We have been asked not to walk _ the lobby today because it's being painted.
47	By the time we got to the train station, the train _.
48	Dr.Smith is a well-respected expert and has _ experience in her field.
49	_ he graduated from the university, he got a job at a good company.
50	If you don't want to get struck in a traffic jam, you should avoid _ during rush hour.
51	Once you start using the new software, you will be able to do your work much more _.
52	This report has to be completed _ 5:00 today at the latest.
53	They made a very _ offer, so we signed the contract.
54	Currently they _ lower prices that any of their competitors.

Table 5.1 continued from previous page

No.	Questions
55	The government will _ new price controls on the industry next year.
56	They will interview each candidate before they _ who to hire.
57	These rooms _ before the conference next week.
58	The new chairs that he bought for the office _ not very comfortable.
59	Everyone is expected to arrive at the meeting _.
60	We will have to come to an agreement _ the end of this month.
61	_ we paid the painters a lot of money, they did a terrible job.
62	After his contract _, he will have to look for a new job.
63	I _ eat at expensive restaurants because I don't have a lot of extra money.
64	The storm caused a lot of damage to the building and we had to buy new for many of the windows.
65	If we _ more time, we would be able to do a more thotough job.
66	You should _ with your boss before committing yourself to that project.
67	They expect _ before noon tomorrow.
68	This store offers a wide _ of office equipment.
69	_ have changed the face of the modern workplace.
70	The train _ Chicago leaves at 4:00 A.M.
71	This car is _ cheap nor reliable.
72	This photocopier is expensive, but it is _ than the other one.
73	_ this paper in the closet next to the box of envelopes.
74	We decided not to rent that office because it was not very _.

Table 5.1 continued from previous page

No.	Questions
75	We realized that nobody had been _ the checkbook.
76	Of all the people who applied for the position, Mr. Sato is the _.
77	Prices are expected to _ before the end of the year.
78	We hired an accountant to the company's financial records.
79	We will have the building _ before we sign the lease.
80	Ms. Lee _ with us since last November.
	Cambridge
81	As a result _ the air traffic controllers' strike all flight have been diverted to alternative destinations.
82	Financial _ are pedicting that a slowdown in consumer spending will affect profit margins
83	In her new position as dean of the university, Dr. Morganti will _ full responsibility for academic affairs and curriculum development.
84	Trasferring our _ facilities to areas with lower labor costs will lead to greater profitability in the long term.
85	Product managers _ performance is considered exceptional will be awarded an annual bonus.
86	With energy prices _ than ever, many petroleum companies are investing in deep water exploration.
87	Brisbane Associates has reavealed that several customers of _ have recently moved to rival brokerage firms.
88	Mr. Walton's physical therapist recommended that he _ the treatment until the sweilling has gone down.

Table 5.1 continued from previous page

No.	Questions
89	Many economists believe that the latest figures show that the risk of inflation has _ slightly over the past six months.
90	Hardly _ of the parts that we ordered are in stock.
91	The warehouse manager has been unable to account _ the missing supplies.
92	Ms. Sato admitted that the sales of her division have been _ but said she expected better results next month.
93	The hotel complext is located five miles _ the international airport.
94	_ Mr. Meyers pointed out at the meeting, centralizing the order processing system will mean standardizing procedures across all business units.
95	The human resources manager has warned labor unlons that prolonged strikes could _ the company's plans to invest in a new plant and lead to layoffs.
	Oxford
96	Ms. Walters _ to another brach, so your new financial advisor will be Mr. Merenda.
97	The restaurant on Main Street offers a wide selection of gourment desserts _ several regions of the world.
98	_ interested in viewing an apartment should contact the property manager to arrange an appointment.
99	A growing _ in the cosmetics industry is the use of natural and organic ingredients.
100	Because of its _ melodies and upbeat rhythms, Bruno Mars' music had broad appeal.

Table 5.1 continued from previous page

No.	Questions
101	The park service asks visitors to behave _ and show respect for wildlife.
102	It is not the company's policy to grant sick leave _ overtime pay to part-time employees.
103	The _ of the Board of Directors is scheduled for Monday.
104	Last year, the number of new university-level textbooks _ by American publishers dropped for the second year in a row.
105	Traffic congestion is _ than usual because of road construction, so it will take us at least an hour to get to the meeting.
106	Investors who lose faith in a company _ sell off their stocks and invest elsewhere.
107	CTC announced on Monday that a European media group is expected to _ its online music store.
108	The Tourist Board of Western is developing a marketing _ to help them increase tourism to the region.
109	Negotiators should be aware that the Prime Minister has a very _ manner of speaking.
110	Jean Grey has been selected to replace Thierry Henry, _ is retiring as president and executive officer of Marteux Pharmaceutical Corporation.

	Longman
111	Both companies are _ the same business.
112	_ there were so many options, everyone was satisfied.
113	If they _ more aware of the trends, they could have avoided bankruptcy

Table 5.1 continued from previous page

No.	Questions
114	Make checks _ to the company.
115	Ms.Holden is both a strong manager _ a skilled negotiator.
116	_ the stokcbrokers said the market was healthy, they refused to invest more money.
117	The seminar will adjourn _ five o'clock.
118	Marketing is important; _ , we're hiring a new public relations firm.
119	The secretary had the messenger _ the envelope as soon as possible.
120	The board meetings usually _ on time.
121	Everyone was disappointed to hear that the company's proposal was _ .
122	Even though the exchange rate was high, we _ from them.
123	It's time to take advantage of current _ rates.
124	_ our office, Mr. James voted against the proposal.
125	Mary is _ an excellent writer.

	Basic
1	When the visitor saw with her own eyes the beach covered with tons of plastic rubbish washed up from around the world, a chill went down her _______.
2	You should wear _______to keep your hands warm. It's very cold outside.
3	Jane has been trying to solve this problem all week, but she still hasn't been able to _______ it.
4	Wilson is a _______ boy. He makes friends at his new school quite easily
5	Thomas bought that pen at a low ______ at a local shop yesterday.

Table 5.1 continued from previous page

No.	Questions
6	It's very ______ of you to help me solve the problem
7	Solutions should be suggested to ________ people from hunting wild animals.
8	The hotel is famous for its spectacular ________ of the sea.
9	Many students are _________ about the coming interview.
10	Tom followed the recipe exactly, but the meat tasted _______.
11	My parents always encourage me to participate in social activities to ______ more life experience.
12	Tom is on his_______to his grandparents' house.
13	There are many ways to_______ goodbye to someone.
14	It's high time you ____________ and started working seriously. Your final exams are coming.
15	There was something wrong with my bike, so I asked my father to _______ it.
16	At first, not so many people _________the danger of Covid-19, so they did not do much to protect themselves.
17	Tickets for such events will be _________ cheap unless you want seats in the VIP areas.
18	The graphics of this book are attractive, but its _____ is not original at all.
19	Peter is an ambitious man who will never _____ till he gets what he wants.
20	I would like to extend my gratitude to all the staff for their _____ support, without which our company couldn't have overcome the crisis.

Table 5.1 continued from previous page

No.	Questions
21	Having your private life scrutinised closely by the public is regarded as part and _____ of being a celebrity.
22	The striker had already celebrated the goal, but the _____ decided that he had been offside.
23	An accomplished chef himself, Ronald is _____ about his use of ingredients and spices, especially when preparing feasts.
24	My aunt excitedly _____ a compliment on the scarf I knitted for her as a birthday present.
25	I can't give chapter and ____, but to the best of my knowledge, it's a line from a sonnet by William Shakespeare.
26	With so many bruises over the body, it is ________ that the child has had a bad fall.
27	The new movie was a ________ as tickets for most of the showings were sold out.
28	Being a wise politician, Mr. Brown tends to reserve his __________ till he knows all the facts.
29	Instead of reading stories from books, Michelle's father usually _____ stories to lull her to sleep.
30	Thousands of _____ packed into the stadium to support their team in the final match.
31	Those boys were excited about the new game in the beginning, but now they have _____ it.
32	A fashionista herself, Helena is _____ about her clothes, especially when making her appearance in public.

Table 5.1 continued from previous page

No.	Questions
33	Fathers can _____ a good example to their children by helping with the household chores.
34	Applications for admission to this university are not processed without a high school _____.
35	The beautiful sandy beach with a lot of sunshine and good foods made his holiday _____.
36	The candidate was rejected as he could not meet all the __________ for this position.
37	These photos ________ many sweet memories of our trip to Hanoi last year.
38	At first, John said he hadn't broken the vase, but later he ________ it.
39	Action films with big stars tend to_______ great public attention.
40	The scientists are working on a drug capable of ____ the spread of cancerous cells.
41	It's time he acted like a ________ adult and stopped blaming others for his wrongdoings.
42	One recipe for success is to stay focused and _____ yourself to whatever you do.
43	It's not my _____to tell you how to run your life, but I think you should settle down and have a family.
44	The aroma of freshly baked bread in the morning has always ____ memories of his childhood home.
45	Schoolchildren shouldn't make fun of those who are intellectually ______ to them.
46	I'm sorry. I didn't mean to ______ your feelings when I said such a thing

Table 5.1 continued from previous page

No.	Questions
47	The film was so intriguing that the audience were all ___ to the screen until the end.
48	A key component of Industry 4.0 is the Internet of Things characterized by the connections of all mobile ________.
49	Many experts support the ______ that children should start learning English as early as possible
50	Much to their disappointment, their start-up project ________, though it had been carefully planned.

	IELTS
1	The building is ____ . It's been ruined and abandoned for years.
2	She lives on a large housing ___ near the centre of the city
3	There are several run-down districts inside the city where the housing is in a bad state, although most of these ___ are going to be replaced by high-rise apartments.
4	The city council are going to ___ the old church and built a new one in it's place.
5	You can't knock down that house; there's a ___ order on it which makes it illegal to destroy it.
6	Sir Richard is the ____ who designed the Lloyds building in London.
7	Some of the problems in our ____ are drug related.
8	The council hope to reduce crime in the town by introducing new ___ facilities so that people have something to do in the evening.

Table 5.1 continued from previous page

No.	Questions
9	The cinema is going to be closed for two months while the owners ___ it
10	If you want to add an extensin to your house, you will need permission from your local council.
11	In the US, the ground floor is called the ___ floor.
12	One way of creating more spcae in a house is to convert the ___ into an extra room
13	Mr and Mrs Smith live at home with their two children. They are a typical example of a modern ___ family.
14	Mr and Mrs Stuart live at home with their aged parents, children and grandchildren. They are a typical example of a traditional ___ family.
15	Mrs. Jones lives on her own and has to look after her two children. There are a lot of ____ families like hers.
16	Some parents need to ____ their children more strictly.
17	When I was a child, I had very turbulent ____.
18	Mrs. Kelly is ____ and finds it difficult to look after her children on her own.
19	Many men believe that ____ is the responsibility of a woman.
20	____ is a particularly difficult time of life for a child.
21	A person’s behaviour can sometimes be traced back to his/her ____.
22	The country has seen a sharp drop in the ____ in the last few years.
23	She has five ____ who rely on her to look after them.

Table 5.1 continued from previous page

No.	Questions
24	_____ crime is on the rise, with over 30 percent of thefts being committed by young people under the age of eighteen.
25	He didn't get a good grade the first time he did his IELTS exam, so decided to ____ it.
26	People who attend university later in life are often called ____ students.
27	Although she had left school and was working, she went to evening classes at the local College of ____ Education.
28	After he left school, he decided to go on to _____ education and applied for a place at Edinburgh University.
29	He received a local government ____ to help him pay for his course.
30	Education helps us to acquire knowledge and learn new ____.
31	Although she already had a first degree from university, she decided that she wanted to work towards a ____ degree later in life.
32	We should make the best of every ____ to learn.
33	Nowadays, _____ education is promoted a lot in schools.
34	A large number of parents are dissatisfied with the ____ education system, and put their children into private schools instead.
35	Because so many students find exams stressful, some colleges offer a system of _____ assessment instead.
36	He has read a lot of books and _____ a lot of knowledge.
37	University students have a _____ who they meet on a regular basis to discuss their work.
38	There were more than 50 students at Professor Bryan's ____ on city planning.

Table 5.1 continued from previous page

No.	Questions
39	The two machines ____ considerably. One has an electric motor, the other runs on oil.
40	The _____ in weather between the North and the South of the country is very noticeable.
41	Many people cannot _____ between lemon juice and lime juice.
42	Children must be taught to ____ between right and wrong.
43	There is a _____ between being interest in politics and joining a political party.
44	Can you tell the _____ between a good boss and a bad one ?
45	The new model of car is very ______ to the old one.
46	Her political opinions are ____ to mine.
47	My friends and I enjoy doing many of the same things. In that respect, we have a lot __________.
48	The nation's economy is largely based on its industry, ___________ a few hundred years ago it was an agrarian country.
49	There seems to be a large _____ between the number of people employed in service industries, and those employed in the primary sector.
50	Some political parties have such similar manifestoes that they are dfficult to

	Oxford2
1	The travel agency will make your travel ____ and send your tickets to the office by the end of the week.
2	Dr. Diop is best known for her ____ contributions to the field of physics.

Table 5.1 continued from previous page

No.	Questions
3	Because of the severe weather, Mr. Kim asked if ____ could leave the office a little earlier than usual.
4	If you ____ additional assistance, please do not hesitate to contact us.
5	The Smithson Bank is well-known for the ____ welcome that it extends to all new employees.
6	Either the organization's sponsors will pay for the building addition ____ we will have to raise the money ourselves.
7	Our recruiter will be traveling to several universities to interview graduating students for ____ in our marketing department.
8	The Fountainview Hotel has rooms available for anyone who plans on ____ in Detroit during the annual conference.
9	Please ____ your supervisor as soon as possible in the event of a machinery failure.
10	The All-Bright safety vest is designed ____ bikers who travel at night.
11	The two companies are now ____ the price Luco Ltd. Will pay Gnose for the property in Quebec.
12	_____ having several years of experience in management, Pedro did not get the promotion for which he applied.
13	_____ the past twenty years, Premium Telecom has rewarded all of its employees with a generous vacation package.
14	Students ____ present a valid identification card can obtain a ten percent discount on tickets to all musical performances.
15	The manufacturer recommends machine-drying at low temperatures; hight temperatures may result in excessive shrinkage and shorten the life of a ____.

Table 5.1 continued from previous page

No.	Questions
16	We will be hiring five part-time employees to _____ staff in the operations department.
17	Because of rush-hour congestion in Farmington several large corporations are implementing ____ work-hour programs.
18	After ____ years of performing for live audiences, stage director Kenneth Ogozi is glad to be working behing the scenes again.
19	Dairy exports ____ for only five percent of the country's total agricultural sales.
20	A local steel manufacturing _____ has purchased the riverfront lot in order to increase its production capacity
21	Although the graphics department _____ acquired a color printer, it has already submitted a requested for another one.
22	This exciting new product is _____ of new software applications that our developers are working on.
23	All Gruner Corporation employees will be invited to the holiday ____ scheduled for next Friday.
24	Great Hope is Toshi Raymond's most inventive stage production _____.
25	The company is confident that its new spokesman will be effective ____ attracting customers within the 18-to-49 year old demographic.
26	When you _____ your loan application, please remember to sign and date the last page.
27	Customers need not pay for shipping because it is ___ in the total price of the item.

Table 5.1 continued from previous page

No.	Questions
28	Both financial advisors recommend investing in pharmaceutical companies, although Paul Laurinen is suggesting a wider _____ of stocks.
29	Water service in the building will be temporarily interrupted _____ city maintenance workers repair the fire hydrants.
30	When you are finished analyzing the survey data, please give ____ report to Ms. Chin so she can copy it.
31	The figures _____ in this estimate are approximate costs and are subject to adjustment at the date of final settlement.
32	Most of our visitors find the information they need here in the main office, though we do _____ receive requests for records that are housed off-site.
33	Many analysis attribute Kramar Industries' ____ success to its state of the art research department.
34	The auditors' report indicates that the firm should _____ its manufacturing division.
35	Since the closing of the community theater, many Corona residents have become strong ____ of public funding for the arts.
36	As a security measure, employees of Kramnick Corporation are encouraged to change their computer passwords _____.
37	Construction on the bridge _____ the two cities has progressed more rapidly than anticipated.
38	To attract applicants who _____ might not be interested, Phantom Chemical Laboratories is offering each new hire a relocation allowance.
39	Agricomp plans to spend 54 million dollars ____ the next six years to build laboratories near its headquarters.

Table 5.1 continued from previous page

No.	Questions
40	Mr. Goo begin his speech by thanking Mr.Takase, who has been teaching him Japanese _____ his arrival in Tokyo.

	Longman practice 2
1	Mr.Du _____ clients' phone calls.
2	Success depends ____ the efforts of the organization.
3	There has been strong competition; ______, the new company has mage great profits.
4	Mr.Shirihara will resign her position as chief _____ officer.
5	The weather report predicts it will rain _______ become colder.
6	The printer _____ paper.
7	The electricity went out ______ we were making coffee.
8	__________ all the negotiators, Ms. Neos seems the most reliable.
9	The sales division reported a 64 percent drop _________ the last sales period.
10	The company is financially sound; ________, there is no debt.
11	Get the invoice _____ upon receipt.
12	__________ time to submit a bid.
13	Our future will be _____ on what services we can provide.
14	If there _________ better communication, I would not resign.
15	__________ the critics and answer their questions.
16	By the end of this century, business _________ greatly.

Table 5.1 continued from previous page

No.	Questions
17	The ______ market has declined in many parts of the country.
18	______ saving money, you will purchase a reliable product.
19	______ one partner has resigned, others are quitting, too.
20	The management makes an assessment _______.
21	The chairman said his _______ would continue his strategies.
22	This region ______ as the costliest place to do business.
23	Since 1990, our customers _______ with out service
24	People either don't have the money _________ they aren't willing to spend it.
25	The group is composed _____ five companies.
26	In order to make more money, Mr. Garcia has decided to ___ a second job.
27	A survey of the _____ shows they are satisfied with their jobs.
28	____ the bad location, the management is confident of success.
29	Company officials must disclose their own ___ affairs.
30	The new business has ____ incorporated.

	Longman Practice 3
31	The report outlines the products for the first quarter _______ the year.
32	The benefits package is impressive; ___, the director promotes only from within the company.
33	This company attempts to make its employees ____ like family.
34	If the bills ______ in five days, the company will seek damages.

Table 5.1 continued from previous page

No.	Questions
35	The bank ___ another branch in Houston within the next year.
36	Could you have the assistant ______ my office before he leaves today ?
37	The _____ was settled on Saturday.
38	Make sure to use an _____ dealer.
39	The printer apologized for ______ two names on the program.
40	Mr. Fox _______ the results tomorrow afternoon.