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Using Feedback to Support Learning Statistics in Higher Education Within a Game-Based Learning Environment

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Work-in-Progress—Using Feedback to Support Learning Statistics in Higher Education Within a Game-Based Learning Environment

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Abstract. Learning statistics is a tedious task and students show a lack of motivation in learning this subject. Game-based learning (GBL) can be efficiently used to enrich the learning experience and can help enhance the curiosity and motivation of learners to keep them engaged. Enhancing curiosity and motivation in a GBL environment through effective feedback can address the issues related to statistics education. This research guides the design of a GBL environment for statistics education to foster improved academic performance through the lens of the information-gap theory of curiosity and the Self-Deterministic theory of motivation. Constructive feedback strategies are used within a game, designed to educate statistics students based on United Nations Sustainable Development Goals (UNSDG). The questions incorporated in the GBL environment are based on Bloom's taxonomy to derive specific learning outcomes and utilize feedback mechanisms to enhance curiosity and motivation in the learners to sustain engagement during the gameplay. This work-in-progress paper describes the design of the game supported by a conceptual feedback framework from a psychological perspective to enhance learners' curiosity and motivation.

Keywords: Immersive Learning, Feedback, Game-Based Learning, Self-Deterministic Theory, Statistics.

1 Introduction

Recent years have seen an exponential increase in data generated through numerous sources. The insights obtained from the collected data through data analysis can be used to make future decisions in the modern data-driven world. Statistics plays a significant role in sifting through the voluminous amount of data. Consequently, it has become crucial for people to grasp basic statistical skills, albeit many students view it as a difficult and onerous subject associated with anxiety, leading to poor academic performance [1]. This poses a significant challenge for teachers to motivate learners to acquire the desired level of statistical expertise. Several studies have explored that traditional teaching strategies are not sufficient to stimulate students' motivation in an academic context [2, 3]. The incorporation of technology with added highly immersive experiences can be a potential solution to resolve this issue.

Curiosity can be defined as a cognitive motivator that sparks the learning process by encouraging information-seeking behavior [4]. Feedback is one of the significant strategies for curiosity arousal and can help educators to build motivational instruction models [5, 6]. The insights gained from the literature review imply that the provision of appropriate feedback can lead to a supportive learning environment providing opportunities for students to exhibit their potential for maximum learning [7, 8].

Game-Based Learning (GBL) is emerging as a promising educational tool and can be used as an innovative medium to help students acquire statistical competencies through effective feedback mechanisms informed by psychological aspects of motivation and curiosity. The popularity of this interactive teaching technique can be attributed to the huge number of children and adolescents' leisure time dedicated to playing video games these days [9]. Previous research asserts GBL shows positive effects on curiosity, motivation, engagement, and learning performance [10, 11].

GBL promotes experiential learning through active participation by providing a highly interactive environment where learners are free to explore and learn safely through trial and error [12]. Many scholars have pointed out that GBL allows an immersive learning experience by sustaining motivation and enhances engagement from a learning perspective [13, 14]. In the context of higher education, students have welcomed the GBL as a part of their classroom learning experience as an opportunity for active and engaging participation [15, 16].

This work-in-progress paper is an attempt to address poor student curiosity and motivation and the use of feedback in a GBL as a potential vehicle to enhance students' learning of statistics in higher education. The main contribution of this paper is to design a framework to enhance curiosity and motivation through feedback strategies within the GBL environment to improve academic engagement and learning in statistics. In the following sections, we describe the literature review related to psychological aspects of curiosity and motivation, effective use of feedback in a GBL environment, and the game design along with the feedback framework implemented in the game.

2 Literature Review

Feedback is acknowledged as a vital element to encourage self-regulated learning by helping compare, monitor, and evaluate the learning process [17]. Providing appropriate feedback allows learners to receive information related to what is already understood and what needs to be understood further so that they may consequently choose the next action or strategy to follow [18]. Curiosity and motivation are critical aspects of learning. A game with a feedback feature allows successful learning by keeping the learners' curiosity and motivation alive [10].

There are numerous psychological theories that can explicate motivational processes and can be analyzed to design an educational game. Providing feedback for common assessment tasks has demonstrated success in academic performance enhancement [19], however, it is important that feedback design is supported by different aspects of psychological theories. According to the information gap theory, the intensity of curiosity goes higher if the information is familiar to the learner but is not too well known [6]. Additionally, Berlyne [20] proposed that external stimulations like novelty, uncertainty, and complexity are required to motivate exploratory behavior and activate the feeling of curiosity. An optimal level of stimulus is required for arousing curiosity and keeping learners engaged by influencing exploratory behavior.

Self-Determination Theory (SDT) is another well-known motivational theory that posits motivation as a powerful force that directs human behavior through the satisfaction of three basic psychological needs of autonomy, competence, and relatedness [21]. GBL can stimulate motivation if the psychological needs of learners are met successfully in that environment [22]. Autonomy plays a key role in designing feedback within a learning setting. Feedback is required to be administered in a non-autonomous manner with the freedom to roam around the learning solution without any restrictions. This allows learners to be more curious and move ahead in the direction of filling their knowledge gap [23] aligning with the information gap theory [6]. Competence is another important aspect of motivation from the SDT point of view that can be facilitated through feedback elements in an educational game. Feedback has the potential to address experiences of the learner's competence in a positive direction [24]. For successful learning, a learner needs to be in an optimal zone of development where they perceive tasks to be sufficiently challenging but within their capacity to accomplish them [21].

Positive feedback is considered to be more influential because it affirms the feeling of competence and autonomy, in accordance with SDT [25]. Positive feedback can help the learner by reducing the feeling of uncertainty about their own strategies and actions [26]. Deci & Ryan [21] indicated that learners presented with unexpected positive feedback experienced enhanced motivation to complete the allocated task. Positive effects have also been demonstrated in response to individualized and meaningful feedback [10]. Prior research has reported that a game that offers optimal challenges supported by appropriate feedback satisfies the psychological need for relevance in the learner resulting in enhanced motivation [27].

According to previous related research, feedback has been shown to have diverse effects on motivation depending on the ways it is delivered to the learner and how the learner interprets the feedback [28]. There are different ways feedback can be incorporated into the game environment to engage learners. Feedback can be provided through specific game design elements representing the interaction between the learner and the learning platform and can be used as a tool to indicate any changes that occurred as a response to the learner's activity during the interaction [29]. The inclusion of feedback might involve the use of game features such as scores, badges, ranks, and rewards. Providing feedback through game mechanisms such as points, levels, etc. can provide extrinsic motivation but there is a greater value in using instructive feedback in textual, numerical, graphical, or oral form because of their informative nature and a connection to learning [30]. Interactivity, rules, procedures, and goals are additional important essential features in the game design that can bring the element of curiosity and

challenge to the game environment [7]. Research shows that feedback is more productive when given through game elements such as textual content, visual progress bars, or numerical scores [31].

The nature and effectiveness of a feedback message can be viewed from different other dimensions such as content, function, purpose, presentation, etc. [32]. The effectiveness of feedback also relates to the way feedback messages are presented to the learner including aspects such as frequency, scheduling, timing, mode, form, etc. [33]. Incorporation of immediate, specific, contextual, and positive feedback can promote long-term changes in the learner's behavior. Timely feedback is considered to be more effective for complex tasks as it helps learners to retain the information. It has been shown to produce better learning performance as compared to delayed feedback and facilitates a better understanding of learners' strengths and weaknesses during the learning process [26].

The insights gained from the literature review imply that feedback practices based on psychological theoretical models along with appropriate characteristics can lead to a supportive learning environment providing opportunities for students to exhibit their potential for maximum learning through the enhancement of curiosity and motivational states.

3 Game Design Using Feedback Framework

This section discusses the design of a GBL environment that can guide learners in learning statistical concepts and enhance their curiosity and motivation by posing some subject-related questions using feedback around a storyline based on the United Nations Sustainable Development Goals (UNSDG) [34]. The game features and feedback strategies have been designed based on the psychological factors discussed in the literature review.

This research is being conducted in the following four phases aligning with the principles and attributes of Design-Based Research (DBR) methodologies [35].

Phase 1: Analysis of practical problems by researchers and practitioners in collaboration.
Phase 2: Development of solution informed by existing design principles and technological innovations.
Phase 3: Iterative cycles of testing and refinement of solution in practice.
Phase 4: Reflection to produce design principles and enhance solution implementation.

The DBR approach allows the creation of prototype solutions by identifying the teaching and learning-related problems based on existing design principles and achieving satisfactory outcomes after iterative cycles of testing and refinement of prototype solutions as well as the design principles [35].

The game has been developed using the Unity 2019 game engine in a 2D environment that allows interactive and immersive environments to be rendered in web browsers. The game has been designed to teach statistics to first-year undergraduate students based on the United Nations Sustainable Development Goals (UN SDGs). The design of the game is focused on two major concepts: developing the narrative (setting, characters, and story) and developing the curiosity and motivational behavior stimulation system using positive and timely feedback based on psychological enhancement strategies such as autonomy, relevance, competence, novelty, optimal challenge, etc. by integrating additional game features such as enhanced graphics, customization, points, rewards, levels, etc. for better player engagement.

In this game, we situate the player in a fictitious UN SDG scenario-based setting where they can interact with a set of non-player characters (NPCs) and artifacts to play the game and acquire the desired information. The proposed game outlines a story around three out of seventeen UN SDGs; 'No Poverty' (SDG 1), 'Good Health and Well-Being' (SDG 3), and 'Quality Education' (SDG 4) to impart statistical knowledge. The game consists of three levels for each UN goal chosen for this research. Players can choose one of the UN SDGs at the start of the game. The player starts their exploration at level one for the first goal chosen, which introduces the basic statistical concepts like Mean, Mode, Median, and Standard Deviation. The relevant scenarios are shown to the player where the curator character provides the background information for the questions presented in the game. The game questions have been set up in Multiple Choice Questions (MCQs) and short answer formats. Questions at all levels in the game have been created using Bloom's taxonomy to develop higher-order critical thinking abilities [36].

Once the player completes all questions correctly, they are allowed to advance to the next level. As the player advances through levels 2 and 3 they are presented with higher-level statistical concepts such as hypothesis testing, correlation, and linear regression. After completing the first goal, the player can choose the subsequent UN goal and complete all the levels for the chosen goal. It is expected that the player implements the knowledge and skills learned through the previous goal in the current goal. The learner is allowed multiple attempts to answer the questions in the gameplay.

Feedback can be presented to the learner in numerous forms [37]. Four types of feedback have been used in this game. The first one is Knowledge of Result (KR) also known as verification feedback which is used to confirm

the correct answer to the player along with a short explanation. Knowledge of the Result (KR) refers to a feedback type that is used to provide the correct answer to the player excluding any additional details. Try-again feedback allows the player to reattempt the question followed by an incorrect answer. Elaborated feedback is another category that comprises the correct answer with a detailed explanation [37]. The learning process of the player is guided throughout the game using a feedback framework (see Fig. 1) that has been designed based on the psychological theories discussed in the literature review.

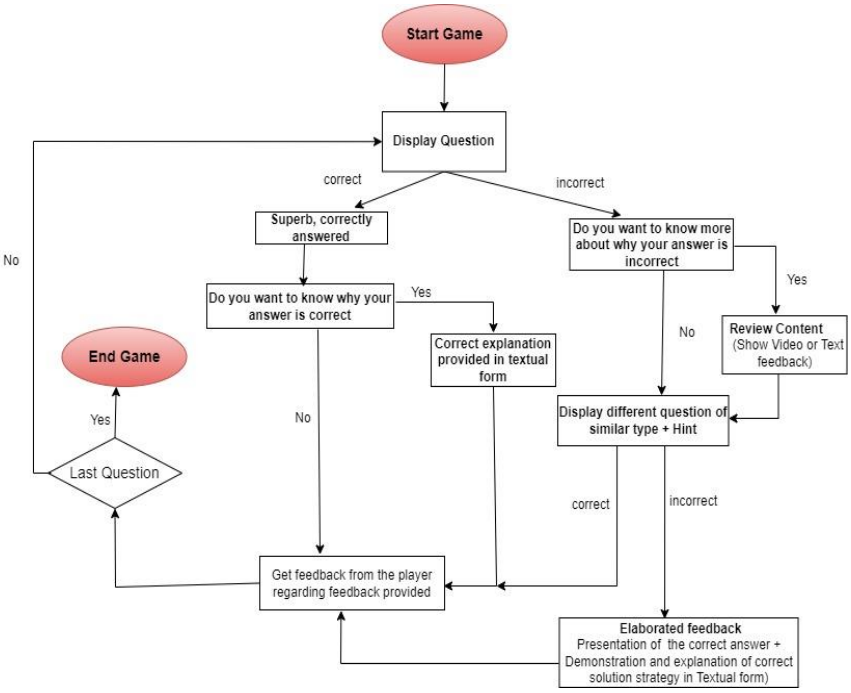

Fig. 1. Feedback framework used in the statistics game

3.1 Implementation of Feedback Framework in the Game

This section discusses how a feedback framework has been implemented in the game to enhance curiosity and motivational behavior in players to improve overall learning performance. The following game snapshots (see Fig. 2 and 3) represent a scenario-based question and a dataset (see Table 1) [38] for UN SDG 'Quality Education' in the game along with the feedback provided to the player based on their attempt at the question.

Scenario: Tim is a year 10 student in an Australian public school and plans to join TAFE to pursue a trade in plumbing soon. His parents, however, disagree with this and urge Tim to enroll in a university for his higher education.

Table 1. Distribution of Australian mean income by qualification [38].

	Unit	Postgraduate	Bachelor's degree	Advanced Diploma/Diploma	Certificate III/IV	With non-school qualification
Males	$	2,132.8	1,955.1	1,638.0	1,583.7	1,137.9
Females	$	1,617.5	1,358.8	1,087.2	926.2	747.1
Overall	$	1,879.8	1,619.3	1,334.3	1,336.1	950.6

Question: Sort through the above dataset from the Australian Bureau of Statistics (ABS) and tell me, what do you notice?

a. The highest education level is most likely to earn a higher income.
b. The males are most likely to earn a higher income.
c. The females are most likely to earn a higher income.
d. There is no correlation between education level and income level.

If the player provides the correct answer to the question on the first try, learners can choose to review the correctness of the answer using verification feedback. For incorrect answers, the player will be presented with an option to review the learning content in text or video format to fill their knowledge gap and can receive another similar question along with a hint to comprehend the concept further, demonstrating the use of try-again feedback as suggested by Shute [37]. Multiple options to receive feedback foster motivation by supporting the autonomous behavior of the player [21]. Incorrect answers in subsequent attempts allow players to receive elaborate feedback combining the correct answer and textual instructions for solving the problem. It also ensures that a specific concept is comprehended fully by the player. At the end of the question, the player is also asked to input their opinion on the feedback provided to them for the specific question.

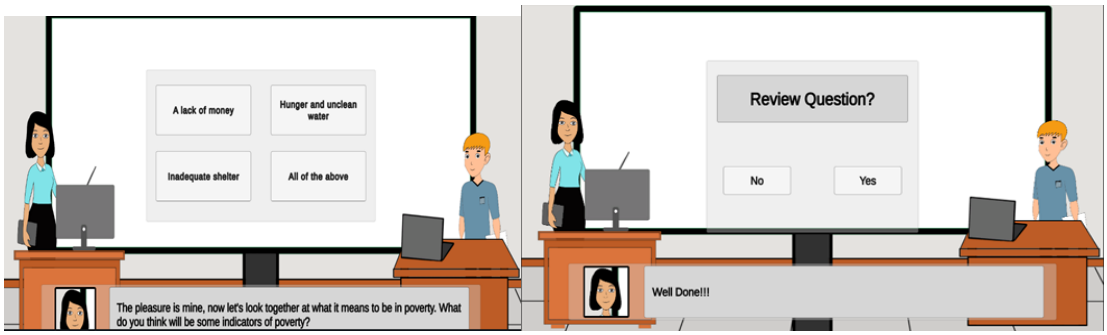

Fig. 2. The statistics game snapshots

Fig. 3. The statistics game snapshots

4 Conclusion and Future Work

This work-in-progress paper reports on the design of a game to enhance learners' curiosity and motivation supported by a conceptual feedback framework underpinned by psychological theoretical models. The insights gained from the literature review imply that feedback practices based on psychological theoretical models can lead to a supportive learning environment providing opportunities for students to exhibit their potential for maximum learning through the enhancement of curiosity and motivational states. We seek to determine whether presenting regular feedback instructions to the learner based on their performance in the game can promote their curiosity and motivation and result in deep learning consequently.

In this paper, we have first explored the significance of curiosity and motivation as means to improve learning experiences and performance through the integration of psychological theoretical models such as Self-Deterministic theory and other curiosity enhancement strategies such as novelty, relevance, and optimal challenge. The paper further explores different types and dimensions of feedback strategies aimed to motivate self-determined learners who are driven by their own desire to succeed in a GBL environment. The feedback strategies have been designed to create an information gap by using stimulants in an autonomous manner to sustain competence and build confidence for improved learning effectiveness.

In the future, we propose to implement the game and collect participants' data through system interaction and self-reporting. The collected data will be analyzed to validate the developed feedback framework.

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