Integrating Generative AI and Progressive Guided Scaffolding Mechanisms in Educational Games to Facilitate Research Design and Statistical Learning

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Abstract
The teaching of quantitative research design in the social sciences is crucial, but learners' learning motivation are limited and there is a lack of more case studies and timely diagnostic guidance. Utilizing case scenarios and giving scaffolding guidance helps to address these limitations. In this study, we designed an educational game that combines case studies and progressive guidance on the Generative AI (GAI) scaffolding. This study develops an innovative scaffolding guidance module for GAI scripts. When a player asks a question, the player will not be told the answer directly. Instead, it gradually guides the player to find the research design problem and think in the direction of appropriate analytical methods. Learners play the role of an anxious graduate student facing a research bottleneck. For a limited time, he can have a discussion with the scaffolding guide to the NPC played by GAI. A total of 18 people participated in the empirical evaluation of this study. The study found that learners had high flow, low anxiety, found the game fun during the game, and had a desire to play again. (All scores are significantly higher than 3, i.e., the median of the scale.) Learners felt that this game enhanced research design thinking more than the conventional curriculum. 72% of the participants felt that the game helped in understanding the concepts of the research design. 78% of the participants felt that the NPC characters would give guiding hints to help learners find the information they need to solve problems online.

Keywords: Educational Game, Generative AI, Scaffolding, Progressive Guided, Quantitative Research Design

Introduction

The teaching of quantitative research design and statistical learning in the social sciences is critical to the development of researchers. In terms of quantitative research design, students and academics often find the units of quantitative research methodology not only challenging but also anxiety-provoking. In a study by Navodya and colleagues (2022), difficulties in writing research papers and deficient statistical knowledge were shown to be the two main reasons for learners' poor performance. In the study of statistics, there is now a greater demand for statistics teaching and expertise in higher education than ever before, but there is a general lack of motivation among students to learn and a feeling that they do not have the necessary skills (Bromage et al., 2021). In addition, there are other limitations, such as limited teaching time, lack of more case studies and timely diagnostic guidance. Many studies have indicated that the use of game-based learning is an effective teaching strategy (Chien et al., 2024). Generative AI is characterized by Large Language Models (LLMs), which are progressive and adaptive to generate interactive conversations. This advantage is combined in the teaching strategy of contextualized games, and then with the use of case scenarios of story scripts, not only can the Generative AI as a scaffolding for immediate feedback, but also guide learners to discover the problem and search for knowledge, resulting in a flow status, which is expected to improve the learning motivation and learning effectiveness.

However, if learners are passive and get their answers directly from the scaffolding, students will not have the opportunity to think cognitively at a high level and select appropriate analytical methods. According to Limbach and Waugh (2010), active learning, appropriate questioning techniques, and structured feedback enable students to higher level thinking and enjoy it. Chien and colleagues (2024) suggest that Generative AI can provide more realistic scaffolding feedback and guidance if it is used as an NPC (Non-Player Character) in role-playing educational games with contextualization. In this study, we design a Generative AI educational game that combines contextual cases with feedback scaffolding. When players ask questions in the game, the Generative AI will not directly tell the players the answers, but rather progressively guide the players to find the questions in the research design and think in the direction of appropriate analytical methods.

Methods

A total of 18 participants were involved in the initial empirical evaluation of this study. The participants were master's degree students from different universities in Taiwan, and they were all over 22 years old. As shown in Figure 1, learners play the role of an anxious graduate student facing a research bottleneck. For a limited time, he can discuss a flawed research design with the scaffolding guide to the NPC played by GAI, then propose a modified research proposal on Google Forms and pass the professor's assessment. As shown in Figure 2, the NPC will not give the player the answer directly, but is only responsible for the role of guidance, the player needs to go to the Internet to check, find the correct information and then confirm with the NPC, the player will get more feedback and confirm the thinking. In this game, players must also utilize their communication, data search and problem solving skills to learn statistical knowledge related to quantitative research design until the end of the game.

Figure 1: GAI Contextualized Game Platform and Google Form Interactive Feedback Mechanisms

Figure 2: Generative AI Progressively Guided Conversations With Feedback Scaffolding

Results and Discussion

Participants in this study completed post-test questionnaires after the completion of the game, including questionnaires on flow status (Table 1), activity anxiety, game acceptance, usefulness and ease of use, and elements of the game (Table 2), and qualitative analyses, and descriptive statistical analyses were conducted using a single-sample t-test. Table 1 shows the descriptive statistical analysis of the learners' flow status after completing the task. The overall flow (M=4.07, SD=0.65) is significantly higher than the median of the scale (i.e., 3). Flow antecedents (M=4.05, SD=0.75), flow experience (M=4.08, SD=0.73), and other flow average dimensions are all high at a median of the scale (i.e., 3). Most of the sub-dimensions had mean scores higher than 4. In the sub-dimension of flow status, learners scored higher on the items of control (M=4.36), playability (M=4.31) and autotelic experience (M=4.31). This indicates that the contextualized design of the GAI educational game enables the learner to have a high sense of self-control and sufficient playability, in addition to which the player is able to participate in the activity from the heart and will feel that the activity itself is sufficiently satisfying to constitute a reward, and will be immersed in the game in order to actively participate in the game tasks and complete the goals.

Table 1: The Mean and Standard Deviation of Learners' Flow

(n=18)				
	M	*SD*	*Z*	Sig.
Overall Flow	4.07	0.65	3.57^{***}	0.000
Flow antecedents	4.05	0.74	3.42^{***}	0.000
Challenge-skill balance	3.61	1.12	2.09^{*}	0.037
Goals of an activity	4.19	0.89	3.40^{***}	0.000
Unambiguous Feedback	3.78	1.07	2.58^{*}	0.010
Control	4.36	0.87	3.51^{***}	0.000
Playability	4.31	0.82	3.47^{***}	0.000
Flow experience	4.08	0.73	3.51^{***}	0.000
Concentration	4.15	1.11	3.00^{**}	0.003
Time distortion	4.14	0.94	3.28^{**}	0.001
Autotelic experience	4.31	0.62	3.64^{***}	0.000
Loss of self-consciousness	3.44	1.25	1.46	0.145

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 2 shows the descriptive statistical analysis of learners' game anxiety, game acceptance and game elements. Overall anxiety (M=2.29, SD=0.91) was lower than the median of the scale (i.e., 3) and reached significance. Moderately low anxiety is an important indicator of sustained flow during gaming activities. In addition, overall game acceptance (M=4.20, SD=0.50), game usefulness (M=4.21, SD=0.61), game ease of use (M=4.19, SD=0.70), and game elements (M=4.16, SD=0.85) were also significantly above the median (i.e., 3) of the scale.

Table 2: The Mean and Standard Deviation of Learners' Game Anxiety, Game Acceptance, and Game Elements

(n=18)				
	M	*SD*	*Z*	Sig.
Game Anxiety	2.29	0.91	-2.63**	0.009
Game Acceptance	4.20	0.50	3.73***	0.000
Game Usefulness	4.21	0.61	3.60***	0.000
Game Ease of Use	4.19	0.70	3.59***	0.000
Game elements	4.16	0.85	3.40***	0.000

Conclusion and Limitations

"Senior Sister Help Me" is an educational learning game developed by this study that lets the player take on the role of an anxious graduate student through the use of GAI progressively real-time feedback and case scenario simulation, with an emphasis on training in research methodology and statistical analysis. It also allows learners to use their communication, information-seeking and problem-solving skills to complete tasks and develop higher-level cognitive thinking skills. The study found that learners had high flow, low anxiety, found the game fun during the game, and had a desire to play again. (All scores are significantly higher than 3, i.e., the median of the scale.) Learners felt that this game enhanced research design thinking more than the conventional curriculum. 72% of the participants felt that the game helped in understanding the concepts of the research design. 78% of the participants felt that the NPC characters would give guiding hints to help learners find the information they need to solve problems online. Future research could increase the sample size and include a control group to compare and analyze the progressively scaffolding-oriented NPC conversational feedback mechanism with the contextualized game using the GAI mechanism, and to explore more deeply the differences in learning effectiveness and higher-level cognitive thinking skills between the research methods and statistical analyses.

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