Exploring the Relationship Between Challenge and Reward for Game Based Learning

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Abstract: The aim of this research is to investigate how problem-solving challenges affect young people's motivation for learning computer programming. It explores the relationship between difficulty and reward as part of a game-based learning application and evaluates the effectiveness of the ARCS learning model when teaching primary school children. Research in game-based learning is based, in part, on the study of the impact of games on students' learning motivation, engagement and outcomes. The ARCS model, developed by John Keller in 1987, is a widely recognized model for designing effective instruction that motivates and engages learners. The model is a cognitive psychology-based learning model that consists of four main elements: Attention, Relevance, Confidence, and Satisfaction. A pilot study comprising primary school teachers was conducted to evaluate the effectiveness of the ARCS model. Two experiments were conducted: the first an experimental group based on the design of the game focussing on the player's experience and evaluation of the difficulty and reward mechanisms. For this group, the game dynamically changes in terms of difficulty and rewards. This is achieved by adjusting the difficulty and rewards through a dynamic player score to maintain player attention, confidence, and satisfaction. The second experiment involved a control group, where the game adopts a traditional linear learning model where difficulty and reward are fixed. For both experiments, data was collected from a feedback questionnaire. The questionnaire was designed to be closely aligned and mapped to the ARCS learning model's four elements. The scores of the results were based on the Likert scale and t-test to determine the significance of the difference in scores between the experimental and control groups. Results based on data analysis of the user study show that the overall mean score of the experimental group is higher (= 4/5) compared to the control group (= 2.2/5) on all four ARCS elements. Further analysis shows that the most prominent teaching impact is on players' satisfaction.

Keywords: Game-based Learning, ARCS Model of Learning.

1. Background and Research Motivation

Research has shown that people invest more time, energy and are more motivated in areas they have a great interest in (Harackiewicz et al, 2016). This underpins the idea that interest is categorized as an important factor that influences learner motivation and engagement with a subject. Educational digital games have been found to enhance learner motivation towards curriculum engagement and improve their learning outcomes. Studies indicated by (Sabirli and Çoklar, 2020) show that the use of educational games to augment learning beyond the classroom, can enhance players' attention and motivations. Further, students who engage with game-based learning have a higher level of positivity towards learning and have improved their academic performance (Zhan et al, 2022).

The challenge when introducing game-based learning to users is to balance the difficulty and reward elements during game play. Research has shown that the setting of game difficulty needs to match a player's game proficiency and skill level, allowing players to maintain high levels of motivation, participation, and enjoyment during game play (Koskinen et al, 2023) though game difficulty levels need to be reasonably set (Kristan et al, 2020). Equally, rewarding a player during gameplay influences their motivation and engagement. Greipl's study found that the reasonable use of rewards in game-based teaching can improve players' participation and motivation (Greipl, 2021). It was also shown that rewards in game-based learning can increase intrinsic motivation, enabling players to develop their learning and problem-solving in a sustainable way (Ryan, 2000).

2. ARCS Model of Instructional Design and Learning

The framework to assess the effectiveness of our experimental design is the motivational pedagogical model proposed by Keller (1987). This model was originally developed to find more effective methods of understanding the influences on the motivation to engage with a learning environment. Keller (1979 & 1983) applied motivation theories to design theory, behavioural theory, and cognitive psychology. Based on research in these areas, Keller (1979) concluded that motivation involves more than extrinsic factors. Learners are not only affected by extrinsic behaviour factors but also by intrinsic factors (Keller, 1979).

Figure 1: Keller's ARCS model for motivational learning

The first provision of the ARCS model and a prerequisite for learning is *attention*; and gaining attention by a defined methodology (or the use of strategies within a learning application such as difficulty settings in games). Secondly, the learner requires a feeling of perceived *relevance*. This refers to the concept of linking the content to a learner's needs. In this case, this would be in the "in-game" activities and how closely they link to the computing curriculum. The recipient must sense that what has attracted their attention is of benefit to their learning and time. The third element in the ARCS model is *confidence*. Confidence is linked to the "in-game reward" and the relationship between difficulty and reward. Solving a more challenging task will give players greater confidence in their ability to solve the next problem. And finally, *satisfaction* arises from solving problems and receiving a reward, but the relationship between difficulty and reward is linked to game-play balance and flow and their impact on player experience. An easy task can make a player bored, equally a difficult task could create anxiety. The relationship between difficulty and reward and how this dynamically changes is a crucial factor for player satisfaction.

Keller's model was not originally developed for game-based learning. However, literature on the use of the Keller's model has been used as a basis for the design, and integration of ARCS into games as an evaluative method for learning. Cheng and Su (2012) developed a game-based learning system to improve self-efficacy for students' learning for an information systems analysis course. For this research, Keller's ARCS model was used as an evaluation tool to assess students' learning. The results show that the learning motivations of students who used the game application had a significant impact on their learning progression compared with student who adopted the traditional face-to-face teaching method. In a second study Hamza et al (2014), proposed an enhanced ARCS+G model for gamification of learning. This model was utilised to identify the motivational requirements of learners during the gamification process and was later implemented in the development of motivational design for e-learning. Kanoko et al (2015) developed and evaluated a game-based learning environment for library instruction based on the ARCS model. In this research, a user study based on an experimental and control groups was carried out to compare game-based and e-learning performance respectively. Results showed that no significant difference in performance was found between the two groups, however three ARCS components were significantly higher for the experimental group when compared to the control group. Camacho-Sánchez et al (2023) assessed the effects of an educational intervention grounded in game-based learning on attention, relevance, confidence, satisfaction, intrinsic and extrinsic motivation, as well as academic performance, utilizing the ARCS motivational design model. The findings of this study revealed significant disparities in the ARCS dimensions between the intervention and control groups. The experimental groups displayed notably lower scores in attention, relevance, confidence, and satisfaction. The intervention had a significant impact on students' perceptions of intrinsic goals and task value, and it exerted a moderate influence on extrinsic goals. The findings suggest that integrating the gamified digital game-based learning approach with the ARCS model can effectively enhance students' motivation, academic performance, and practical knowledge in higher physical education. Koceska et al (2024) presented work on the design and development of an educational game for children with special educational needs (SENs). The study combined the ARCS motivation model with a game design model to develop a user interface through which learners can control learning objects using their physical movements. The validation of the design was done using the quality assessment instrument called LORI (Learning Object Review Instrument).

3. Research Design

The research conducted for this work-in-progress paper is based on a pilot experimental study. The participants in the experiment are primary school teachers who deliver on the computing curriculum with a teaching experience ranging between one and 15 years. The experiment and questionnaire were conducted online. All participants agreed that the experimental group's game design was more biased towards their preferences, but the aspects they favoured differed. All participants took part in this study on an anonymous basis. The total sample size and number of participants for this study = 10 (N= 10). The number of participants was equally split between the experimental and control groups. The experimental group experienced the game based on the

ARCS learning model, with a focus on exploring the effects of difficulty and reward on players. Here, difficulty and rewards during game-play change dynamically according to the player's "in-game score" as a way of maintaining player attention, confidence, and satisfaction. The control group experienced the traditional linear educational model in which difficulty and rewards are fixed. The evaluation of this study is based on the analysis of data collected from feedback questionnaires. The questionnaire was designed to be closely aligned and mapped to the ARCS learning model's four elements shown in Table 1 below.

Table 1: Questionnaire mapped to Keller's ARCS model of learning.

Keller's motivational model	Questions aligned with Keller's model of learning
Attention	-Your attention was attracted already at the beginning of the game. -The ordering and sequencing of shapes, forms and sounds of the game affects the learning process.
Relevance	-The software allows you to take a break and continue later. - You intend to recommend the application to others.
Confidence	- You use correct terms while referring to the application. - You have the impression (at first sight) that this would be an easy game to play.
Satisfaction	- The procedures of the application motivate the user. - The application is entertaining to the user.

Feedback from both sets of participants were quantified into scores based on Likert scales and t-tests to determine the differences between the experimental and control groups. Details of the attained results and their evaluation are presented in Section 3.

4. Results and Evaluation

The results of this pilot experiment are shown in Figure 2 below. Figure 2 shows that the scores for each of the ARCS model of learning for the experimental group are higher than those experienced by the control group. The overall score of the experimental group was 4 (out of 5) while the overall score of the control group was 2.225 (out of 5). Looking at each element of the ARCS model (Attention, Relevance, Confidence, and Satisfaction), we note that their scores are 4, 3.9, 4.1, and 4 for the experimental group and 2.5, 2, 2.4, and 2 for the control group. Combining the above data and the mean difference shows that the experimental group's scores are higher than the control group on all four ARCS elements. We can deduct from these results that the effect of dynamically changing the in-game difficulty and award based on players' "in-game score" incentivises players to maintain attention, confidence, and satisfaction and overall perform better than the traditional linear education model.

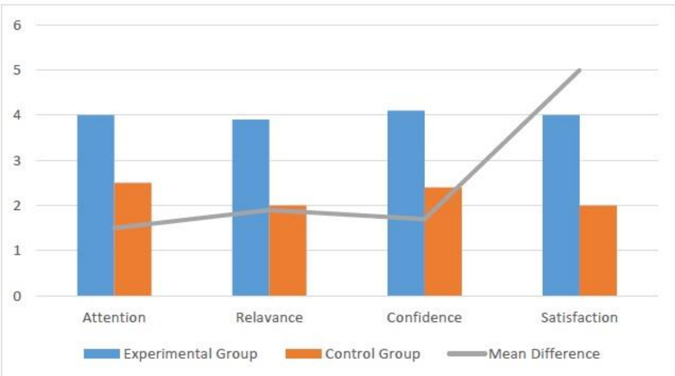

Figure 2: ARCS model mean scores for experimental and control groups

Given the small sample size of our participants, a t-test inferential statistic was implemented to assess whether the differences in the attained results are significant. In turn this enable us to generalise our finding and make inferences about users beyond our data for this pilot study. Equation 1 and Table 2 below show the formula for the t-Test and the t-Distribution table in terms of degrees of freedom according to different α.

Equation 1: t-test calculations formula

$$t = \frac{(\overline{X}_1 - \overline{X}_2)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

Table 2: t-Distribution table

***t* Table**

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850

Looking at Table 2 and given that the total sample size of the combined group is 10, the degree of freedom in the t-test will be calculated by subtracting one from the total number of participants (N-1 = 9). The experiment is based on one tail, and the chosen significance level α is usually taken as 0.05 or 0.01. For this experiment α = 0.01 was selected because a higher significant difference was desired in the results. When the calculated t-test is greater than the corresponding t-quartile, it indicates a large difference. This can be seen in Figure 3 below.

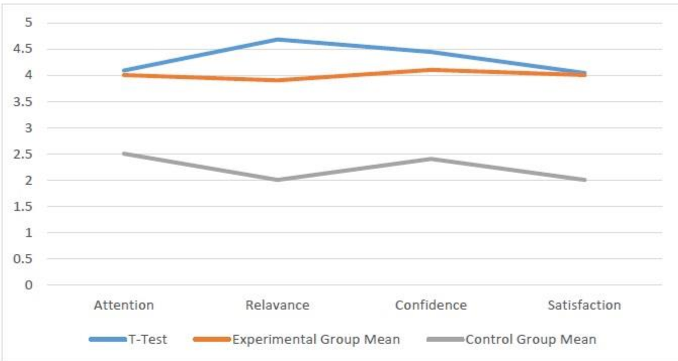

Figure 3: The parameter is a line graph of the t-test values calculated as the mean of the experimental and control groups at α = 0.01 and df = 9.

The t-tests for Attention, Relevance, Confidence, and Satisfaction were calculated to be 4.09, 4.68, 4.44, and 4.04. These figures are all greater than the corresponding t quartiles at α=0.01 and df=9. They indicate that the experimental and control groups have more significant differences in the means for all four components of the ARCS model.

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