Investigating the Intrinsic Integration Hypothesis for the Design of Game-Based Learning Activities

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Abstract

The intrinsic integration hypothesis proposes that using core game mechanisms to teach learning material makes educational games more fun to play and better for learning. Our study tests the intrinsic integration hypothesis with two educational versions of Battleship that were designed for this experiment, in the domain of complex numbers. We examine the learning gains and motivation of 58 participants who interacted with either the intrinsically-integrated or extrinsically-integrated version of the game. Our results contradict previous findings supporting the intrinsic integration hypothesis: participants reported similar levels of motivation from both versions of the game and participants who interacted with the extrinsically-integrated version learned significantly more as measured by pretest to posttest gains. This work contributes empirical data to the debate concerning intrinsic integration, and it highlights the need for additional studies exploring the integration of learning material into educational games.

Keywords: Intrinsic integration; games; student learning

Games and Student Learning

Educational games aim to make learning fun by incorporating game elements, such as fantasy, challenge, and competition, into instructional activities (Malone & Lepper, 1987). Three recent meta-analyses found that overall, students learn more from educational games than from traditional activities like standard classroom instruction (Sitzmann, 2011; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013; Clark, Tanner-Smith, & Killingsworth, 2016). While this result is encouraging, there are two caveats: (1) not all studies found a positive effect of games, and (2) comparing games to other activities does not inform on how to best design games to maximize learning and engagement from them. Thus, there have been calls to test the effect of various design factors on student outcomes, referred to as the *value-added* approach to educational game research (Mayer, 2011). This approach involves comparing student learning and/or motivation with a basic version of a game to the outcome of one that includes an additional design feature.

As an example of the value-added approach, studies have examined the effects of cooperation and competition in educational games (Ke & Grabowski, 2007; Plass et al., 2013). Ke and Grabowski (2007) compared the impact of games involving cooperative competition, individual competition, and a non-game control condition on math learning and attitudes among fifth-grade students. Participants in both game conditions learned more than those in the non-game control condition. Moreover, attitudes regarding math were significantly better in the cooperative game condition than in the other two conditions. Plass et al. (2013) also examined the effects of cooperation and competition on learning outcomes. Learning, assessed by pretest and posttest scores, was only significantly higher in the competitive condition compared to the control condition that did not include competition or cooperation. While the collaborative condition had the lowest in-game performance of all three conditions, it produced the most positive affect as measured by intention to play the game again and to recommend it to others.

As another example of the value-added approach, Conati and Manske (2009) assessed the value of adding an agent delivering adaptive hints in an educational game. The hints were generated based on a user model of student knowledge. No difference was found between the agent version of the game and a control version without the agent. Conati and Manske (2009) speculated that the reason for the lack of an effect may have been due to an inaccurate user model, the challenge of fostering learning in the target domain, and/or the hints interrupting the flow of the game.

An area within the value-added approach that has not received much attention is the integration of a game's motivating elements with the learning material. A recent meta-analysis by Clark et al. (2016) found only one experiment that investigated this factor, involving a game that completely separated the learning mechanisms from those designed for engagement with the game – this experiment will be described in the next section.

Extrinsic and Intrinsic Integration

How should game elements be integrated with the learning elements? Kafai (1996) anecdotally observed that students tasked with designing educational games took one of two distinct approaches. He called this dichotomy *extrinsic* vs. *intrinsic* integration. The extrinsic approach used the game as a form of 'sugar-coating:' players in the game were rewarded for answering questions on the learning material with the opportunity to continue playing the game. Thus, the game play was clearly separated from the instructional activities. The alternative to this approach is the intrinsic approach, which involves using the game's core mechanisms to present the learning material, thereby integrating the learning activities with game play. Thus, in contrast to the extrinsic approach, with the intrinsic approach there is no distinct separation between game activities and learning activities.

Habgood and Ainsworth (2011) proposed that students would learn more from intrinsically-integrated games than extrinsically-integrated games (referred to as the *intrinsic integration hypothesis*). Their experiment compared two versions of an educational game called Zombie Division, designed for middle-school children. In the intrinsically-integrated version, players navigated their character around a dungeon and used division to defeat computer-controlled opponents represented by skeletons. Importantly, while this version required students to practice division, doing so was the primary way to progress through the game. In contrast, in the extrinsic version the learning material was removed from the game portion and isolated to quizzes presented between game sessions. Results indicated that students who played the intrinsically-integrated version improved significantly more from pretest to posttest and reported higher engagement.

While the Habgood and Ainsworth (2011) results are encouraging, they warrant replication. Because the math activities were moved to quizzes in the extrinsic version of the game, the gameplay in that version became less challenging, as acknowledged by the authors and reported by the students who played the game. Lack of challenge may have diminished learning outcomes from this version. Additionally, interleaving the questions with gameplay sessions changed the instructional sequence of the extrinsic condition. Thus, the decreased challenge and different instructional sequence could have biased the results.

While intrinsic integration does have the benefit of not interrupting players during game play to have them complete educational tasks, it also has potential downsides. One is related to transfer. The learning material in an intrinsically-integrated game is often presented in a context different from the one in which it will later be applied and tested. Students find it difficult to transfer knowledge learned in one context to a different one even when the fundamental concepts are the same (Kaminski, Sloutsky, & Heckler 2009). Intrinsic integration could also be disadvantageous because it requires the player to simultaneously cope with two competing sets of demands, stemming from the educational and game elements, which could increase extraneous cognitive load.

Given the above considerations, the goal of the present work was to test the intrinsic integration hypothesis through an empirical study.

The Present Study

To test the intrinsic integration hypothesis, we created a paper-and-pencil educational game designed to help students practice concepts in our target domain of complex numbers. The game was based on *Battleship.* To play Battleship, each player secretly plots their ships onto a two-dimensional plane and then fires upon their opponent's ships. The first player to correctly guess every coordinate containing a ship wins the game. While the original Battleship was not explicitly educational, the two-dimensional nature of complex numbers makes them particularly suited for intrinsic integration into Battleship, as the coordinates on the two-dimensional board can be substituted with complex numbers.

Participants

The participants (N = 66, 35 females) were undergraduate students at a Canadian University recruited via Sona and posters displayed around campus. As the game in our study was played in pairs, participants were asked to come to the study with a friend or classmate, instead of being paired with a stranger. This was done to facilitate interaction during gameplay, as both participants would already know each other. Each participant was compensated with their choice of either course credit or $20.

Materials

Intrinsic and Extrinsic Versions of Battleship We created two versions of Battleship; both were played with pencil and paper materials. In each version, participants had two game boards, printed on paper, also referred to here as "planes". One game plane was private as it was positioned behind a screen and players were instructed to keep it hidden from their opponent. They were asked to draw their ships on this private plane at the start of the game. The second plane was public and was used during the game to indicate players' shots on their opponents' ships (done by drawing the shot on the public game plane). Because our goal was to only vary the intrinsic/extrinsic dimension while keeping other aspects of the two game versions as similar as possible, the game play was almost identical in both versions.

In the intrinsic version, the game board corresponded to a complex plane (see Figure 1, left). A turn began with each of the two players selecting where they would place their next shot on the public plane. To do so, they indicated the chosen location by writing down the rectangular form of a complex number corresponding to that location on the '*shot list*,' which was a second piece of paper labeled with turns (see Figure 1, right). For example, if a participant thought their opponent's ship was in the top-left of the plane, then

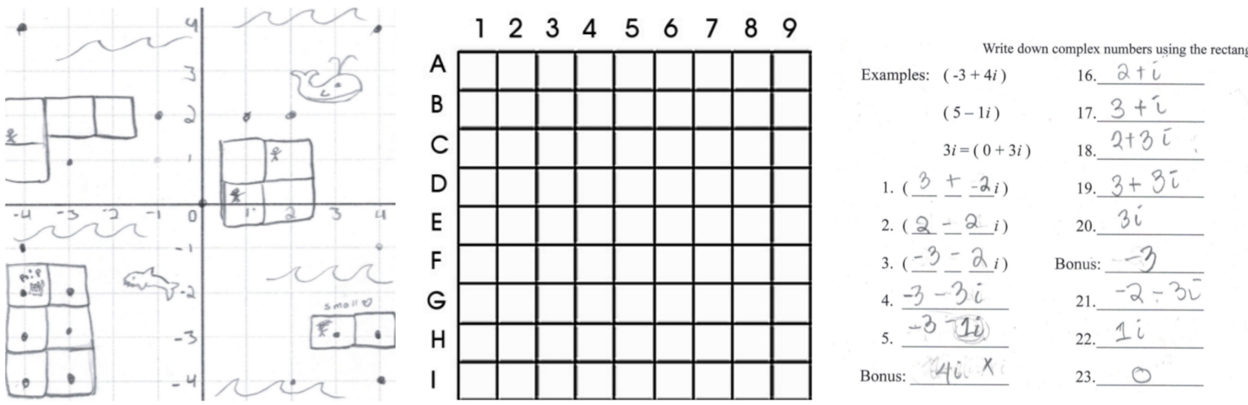

Figure 1: The complex plane used in the intrinsic condition (left), marked with a participant's game moves, the plane used in the extrinsic condition (centre), shown without any entries, and the response sheet used in both conditions (right), shown with a player's entries.

they would write (-4 + 4*i*). When both shots were written down, the players checked each other's entries for the correct format. The participants could not continue playing until the correctness of their entry was confirmed by their opponent. However, the experimenter did not verify the answers and, if asked, referred participants to the examples provided by the game material (the screen hiding the private game planes had a recap of the instructional material and another sheet provided examples of complex number problems). Thus, the responsibility was on the participants to verify their entries, and they had resources to help them do so. This did not take away from the competitive aspect of the game as the competition came from locating the opponent's ships, like in the original Battleship. Once both players were satisfied their opponents had written a complex number in the correct format, they checked if their opponent's shot struck one of their ships, and they indicated the result on their public game board. Note that "a shot" corresponded to the complex number that they had written down. Thus, the learning material was intrinsically integrated with the game mechanisms: to play the game, participants had to apply complex number knowledge.

The extrinsic version was identical except for two key differences. First, the game board was based on the standard *Battleship* game and so corresponded to a coordinate plane where the axes were labeled with letters in the left margin and numbers on the top margin (see Figure 1, center). Second, at the start of a turn, participants first randomly chose a coordinate on the complex plane from a deck of cards. Thus, in this version, the coordinate did not represent a shot on the opponent. Like in the intrinsic version, the players translated that coordinate to a complex number and had their opponent check it. In contrast to the intrinsic version, however, they then specified the shot on their opponent using a letter-number pair corresponding to the axes' labels on their planes (e.g., A-2). This was done to create a divide between the learning material and the game material, thereby making the game extrinsically integrated.

After every five shots participants in both game versions were asked to multiply the previous complex number by the imaginary unit, writing their answer on the shot list. This was considered a bonus question and a correct answer was rewarded with an extra shot.

The game and study materials were refined via pilots.

Complex numbers lesson To provide the domain background needed to play the educational game, participants were given a paper-based lesson we developed on the complex number system. The lesson consisted of a two-page description with accompanying illustrations.

Test Materials A pretest and posttest were used to measure participants' complex numbers knowledge before and after they played the game. Each test consisted of twenty questions.

Instruments An online survey was used to collect motivational and affective data, in addition to basic demographics. The motivational and affective survey used a Likert scale and included: (1) the Intrinsic Motivation Inventory (Deci & Ryan, 2003) based on four sub-constructs, including interest, competency, choice, and pressure; (2) some custom questions measuring participants' willingness to re-engage with the instructional material in the future (e.g., "I would use the game to teach complex numbers"). Several other instruments were used to measure mindset and math attitudes but results from their analysis are not included here, so they are not described.

Design

We used a two-factor (2 x 2) mixed design. The first factor, *condition*, was a between-groups variable with two levels (intrinsic and extrinsic, corresponding to intrinsically-integrated and extrinsically-integrated game versions, respectively). The second factor, *time*, was a within-groups variable with two levels (pre and post, referring to pre-game play and post-game play, respectively). Participants were assigned to a given condition in a round-robin fashion.

Procedure

Each session was conducted individually and included a pair of participants. Each dyad spent approximately 90 minutes in the study, with the exact duration varying based upon the amount of time participants spent on the instructional material as well as the pretest and posttest. The procedure for the two conditions was the same. After providing consent, participants were seated back to back and (1) read the complex numbers lesson, and (2) filled in the complex numbers pretest. Once both participants had finished the pretest, they were asked to move to the game table positioned in the centre of the room where they sat across from each other, and the gameplay phase began.

Participants were provided with all the game materials and instructions on how to how to play the game (for details, see Nidd, 2018). After both participants had plotted their ships according to the game rules, they were given 35 minutes to play the game. Any questions relating to complex numbers were answered by referring the participants to the examples in the instructional materials that were provided as well as the recap of the lesson on each of their game screens. When the time was up, participants were given the choice to play for another five minutes if they wanted. This was done as an additional measure of motivation.

Directly after the game phase, participants were moved back to their initial seats where they were seated back-to-back and completed the (1) posttest and (2) the study questionnaires.

Table 1: Descriptive statistics for the test scores.

	Extrinsic		Intrinsic	
	M	*SD*	*M*	*SD*
Pretest (/20)	4.93	2.85	4.83	3.71
Posttest (/20)	10.39	3.79	8.73	4.38
Difference (post - pre)	5.46	2.43	3.90	2.64

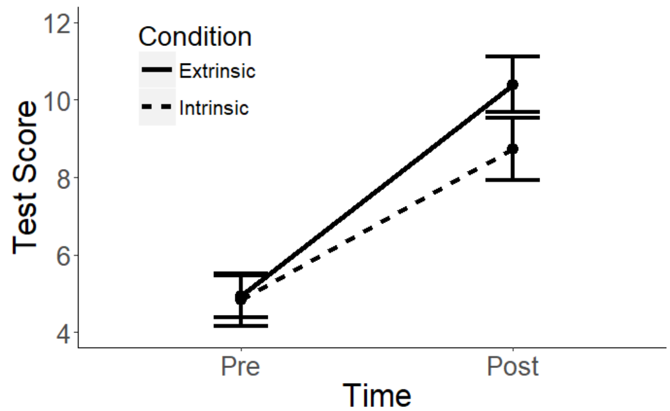

Figure 2: Interaction between time and test score, indicating higher pre to posttest learning in the extrinsic condition.

Results

The analysis is based on 58 participants (eight participants were not included either because they were at ceiling on pretest, i.e., 90% or higher or because their performance decreased from pretest to posttest). The analyses, which were conducted with the statistical software *R*, used inferential statistics that assume independence between participants. Since participants worked together during the game, there was a potential concern that their learning-related data might be dependent. To check for this, a correlation between pretest to posttest difference scores of both individuals in a pair was conducted. The correlation between the learning outcomes of paired participants was not significant and corresponded to a very small effect, $r(31) = .05$, $p = 0.78$, suggesting that the independence assumption was not violated. Thus, we continued with our analysis testing the conditional effect on (1) learning outcomes and (2) motivation.

Are Intrinsically-integrated Games Better for Learning?

To check for equivalence between the two conditions on *a priori* knowledge, participants' pretest scores were compared. The scores were distributed fairly evenly between the two conditions and while they were slightly positively skewed (skewness of 0.90 and 0.60 respectively), this was within the bounds of normality. As shown in Table 1, the mean pretest scores were similar between the two conditions, with no significant difference between them as indicated by an independent samples t-test, $t(54.05) = 0.11$, $p = .91$.

As is standard, learning was measured by the difference between a participant's performance on the pretest, completed after they read the instructional material but before they played the educational game, and their performance on the posttest. The descriptive statistics are shown in Table 1. The higher mean difference in the extrinsic condition suggests that participants who played the extrinsic version of the game learned more, because they improved more from pretest to posttest.

To analyze the impact of the extrinsically- and intrinsically-integrated versions of the game on learning, a two-way mixed ANOVA was conducted with test scores as the dependent variables, condition (extrinsic vs. intrinsic) as the between-subjects independent variable, and time (before and after the experimental intervention, i.e. game play) as the within-subjects independent variable.

In general, collapsed across conditions, participants improved from the pretest to posttest as indicated by the significant main effect of time on participants' test scores, $F(1, 56) = 194.62$, $p < .001$, $\eta_p^2 = .78$. While this demonstrates that the instructional material improved learning overall (collapsed across the two conditions), of primary interest is the time by condition interaction, which examines the effect of condition on learning (i.e., pretest to posttest differences). This interaction was significant, $F(1, 56) = 5.49$, $p = .02$, $\eta_p^2 = .09$. As shown in Figure 2 this interaction indicates that participants who played the extrinsic version of the game learned significantly more than those who played the intrinsically-integrated game.

Are Intrinsically-integrated Games More Motivating?

The effect of game version on participants' motivation was measured by (1) Intrinsic Motivation Inventory (Deci & Ryan, 2003), (2) the custom questionnaire measuring self-reported re-engagement, and (3) the behavioral data on whether participants chose to continue playing the game for an additional five minutes after they were told they could stop. Like the Intrinsic Motivation Inventory, this additional measure was derived by averaging a participant's answers to the custom set of questions that asked them to report their willingness to re-engage with the instructional material using a 7-point Likert scale.

Descriptive statistics for this analysis are in Table 2. There was little difference between the two conditions in terms of the motivational variables. This was confirmed by a series of independent-samples t-tests comparing the five measures of participants' motivation in the two conditions. As shown in Table 3, none of the analyses were significant (while this analysis did not control for familywise error rate, doing so would not have changed the results, as none of the findings were significant). A chi-squared test of independence was performed to examine the relationship between the game version and participants' decision to continue playing for an additional five minutes. Like the other measures of motivation, the difference between the two conditions was not significant, $X^2(1, 29) = 0.016$, $p = .90$.

In summary, there was no evidence that the version of the game, intrinsic versus extrinsic, impacted participants' motivation. However, collapsed across condition, participants had fun playing the game. Participants reported that they were interested in the instructional material as indicated by high scores on the motivational questionnaire, and a third of them chose to stay longer than they needed to. Anecdotally, these measures are further supported by the verbal reactions of participants. One person remarked that the experiment was "really fun actually. If math was like this, I'd enjoy it a lot more." Another exclaimed upon receiving the post-test, "Battleship actually helped with this!" When the same participant – who was vocally anxious about math – forgot to take their shot upon the opponent's ships and immediately drew another complex number question, they joked: "Sorry, I just love math." Additionally, some participants asked if they could keep their game sheets to finish the game at home, and one participant even asked if they could buy the extrinsic version as they thought it was an improvement on the original Battleship. These measures and anecdotal reactions suggest that the educational game was motivating for participants.

Table 2: Descriptives for the five motivation subscales in each condition.

	Extrinsic		Intrinsic	
Subscale	*M*	*SD*	*M*	*SD*
Interest	5.00	1.64	5.01	1.48
Competency	4.27	1.41	4.62	1.44
Choice	5.03	1.42	5.13	1.40
Pressure	2.66	1.37	2.99	1.22
Re-engagement	4.17	1.27	3.95	1.44

Note. The maximum score for each subscale is 7

Table 3: Results for the conditional effect on each subscale of the motivational questionnaire.

Subscale	*df*	*t*	*p*	*d*
Interest	54.35	0.03	.98	.01
Competency	55.89	0.94	.35	.25
Choice	55.57	0.28	.78	.07
Pressure	54.20	0.96	.34	.25
Re-engagement	55.82	0.61	.54	.16

Discussion

Our results do not support the intrinsic integration hypothesis, as participants who played the intrinsically-integrated version of the game were not more motivated and did not learn more than those who played the extrinsic version. On the contrary, those who played the extrinsically-integrated version of the game learned significantly more.

Why did extrinsic integration result in more learning than intrinsic integration? As we already noted, one of the potential disadvantages of intrinsic integration is the need for transfer. In the intrinsic game version, the complex numbers corresponded to the coordinates of players' ships. Consequently, the numbers represented two constructs: they were concrete representations of a location on the game board, and they were the abstract representations that would later be tested. By having participants play and interact with these representations, intrinsic integration potentially made it more difficult for participants to see the complex numbers they were using as being important in themselves (Brown, McNeil, & Glenberg, 2009; Uttal, O'Doherty, Newland, Hand, & DeLoache, 2009). Importantly, this potential disadvantage of intrinsic integration is not an artifact of our game design but rather a requirement of intrinsically integrated games. In contrast, the extrinsic version may have made it easier for participants to focus on and learn the mathematical principles by separating the abstract target knowledge from the more concrete interactions between the player and the game state (Uttal et al., 2009).

A second potential explanation for our findings pertains to cognitive load. The intrinsically-integrated game may have increased participants' extraneous cognitive load, as the tasks related to game play and complex numbers were integrated. In other words, the intrinsic version had players pick a shot, practice the learning material, and then resolve the shot. In contrast, the extrinsic version separated these tasks. These competing demands imposed by the intrinsic game and the domain questions may have diminished players' learning by increasing the load on their working memory (Clark, Nguyen, Sweller, & Baddeley, 2006). Similarly, the extrinsic version could have made working memory available for the mental processing that is required for learning. Since we did not measure cognitive load, this conjecture awaits future research.

Our results are not aligned with those from Habgood and Ainsworth's (2011) experiment. A potential explanation for these differences relates to control of the instructional sequence and challenge levels in the two versions of the game. Our experiment maintained similar instructional sequences between conditions by incorporating the extrinsic learning material throughout gameplay. In contrast, the prior study divided the learning material and game into lengthy blocks that may have disrupted user engagement more than is necessitated by extrinsic game design. This separation in the prior study also reduced challenge, a factor known to impact engagement with games (Garris, Ahlers, & Driskell, 2002). By removing the learning material from the game mechanism, players no longer had to solve a problem to progress through the game. This was reported by participants as they remarked, "it just tells you what to use" and "it's not a challenge" (Habgood & Ainsworth, 2011, p. 28). This difference was not present in the two game versions used in our experiment.

Another potential reason that our results do not support the intrinsic integration hypothesis relates to an interaction between the type of integration and cooperation/ competition. Specifically, adding a second player may have 'gamified' the non-game elements. For instance, participants answering the non-game domain questions in the extrinsic version of Battleship were still competing against their opponent to get the right answer. This aspect of the extrinsic game is comparable to a trivia game, as a correct answer was required to take a shot in the game of Battleship. Indeed, an educational game could consist of just this competitive quiz aspect (as in Ke & Grabowski). In Habgood and Ainsworth's (2011) game, completing the domain questions in the extrinsic version was likewise necessary to play the game, as participants needed to repeat the quiz if they did not get a passing score; however, this requirement could seem like a prerequisite in a single-player game, whereas it could seem like an element of the game when another player is involved.

There are also several methodological differences worth noting between our experiment and the previous work that did support of the intrinsic integration hypothesis (Habgood & Ainsworth, 2011). Our experiment used undergraduate students as opposed to primary school students between the ages of 7 and 9. Additionally, we recruited these participants in pairs instead of recruiting entire classes. Although similar domains were used, the target knowledge was more advanced in our experiment to match the participants' education level. The games in the two experiments differed in fundamental ways: our game was implemented as a board game rather than a video game, another human player was involved in our game, and the narrative elements were more pronounced in Habgood and Ainsworth's game. The measure of motivation also differed as Habgood and Ainsworth used qualitative interview data paired with a second experiment that measured the amount of time spent in the intrinsic and extrinsic versions when given a choice. In lieu of this, our experiment used the established Intrinsic Motivation Inventory to measure participants motivation to engage with the educational game.

In conclusion, our experiment contributes empirical data to the debate concerning intrinsic integration and educational game design. Our findings indicate that extrinsically-integrated games are better for learning and similarly motivating as intrinsically-integrated games. Ultimately, given the relatively few studies in this area and the lack of agreement between findings from the ones that do exist, our work highlights the need to further explore factors related to educational game design and their impact on student learning and motivation.

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