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Shared learning objectives in interdisciplinary projects: Game design in a Sino-Scandinavian context

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This article presents an explorative mixed method evaluation of this course. The research design had two phases with an initial qualitative analysis resulting in a set of observations that were tested in the second, quantitative phase. A total of 34 students from a range of disciplines participated in a two week course. The quantitative analysis shows that art (n=13) and technology (n=14) students' reported very similar experiences and similar insights into core learning objectives. This study shows that deeply interdisciplinary project-based courses, with shared learning objectives can successfully be conducted even in a context with no prior experience of such approaches.

Keywords

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Introduction

Digital games have grown to be a major part of media consumption in most parts of the world. With increases in both undergraduate and postgraduate programs, the academic training of game developers has increased in western countries (Ashton 2009; Zagal 2013; Berg Marklund 2016). Digital games research and game studies have established themselves as research areas that have attracted scholars from several disciplines (Quandt et al. 2015; Martin 2018). One central concept in game development is that game design is a second-order design problem (Salen & Zimmerman 2004). This means that the designer defines the rules of the game, but *the dynamics of the gameplay emerge* when players interact with these rules (Hunicke et al. 2004). The goal of design is user *experience*. Because it affects the way that game-development projects should be organised, this facet of game design is central for all disciplines involved in game production. There are many reported examples on the use of project-based learning to teach game development (e.g. Sumner et al. 2008; Bidarra et al. 2008; Hogue et al. 2011). Even if some of these studies include elements of interdisciplinarity, the learning objectives are formulated from a disciplinary perspective.

This study reports the results of a Sino-Scandinavian collaboration in which teachers designed and delivered a two-week, project-based course focused on the second-order game-design problem to a group of students from a range of disciplines. This article uses “functional games” as synonymous to serious games. “Functional games” is the term predominantly used in China; hence its use here in course material and student questionnaires. The teachers came from the backgrounds of game design, functional games and game development. The course was developed through a number of workshops where the participating teachers applied their long experience of teaching game design within a range of disciplines.

The course was evaluated in an explorative, mixed-methods research study. Teacher observations and student self-reflections were triangulated in a qualitative first phase, resulting in a set of observations. These observations were validated in a quantitative second phase based on responses to a Likert-scale questionnaire.

The quantitative analysis showed that art (n=13) and technology (n=14) students reported very similar experiences and similar insights into core learning objectives. Both technology and art students reported that the central learning objectives were achieved. Both groups reported equal contributions to ideation and game design, and they identified paper prototypes and play-testing as the most important course elements. These two elements are both at the core of addressing the second-order design problem. The study results indicate that a project-based, interdisciplinary approach with shared learning objectives can be successful even when students have no prior experience of this type of course. The results have clear implications for the teaching of game development. It may also be relevant for other deeply interdisciplinary areas where central learning objectives are shared across disciplines.

Background

Digital games as an academic field

Academic training in digital game development has a relatively short history (Ashton 2009). There are traditions specific to each of the contributing disciplines (e.g. art, programming and narration). However, the unique challenges in digital game development affect how students should be trained for the profession. Educational programs specifically targeted at game development have grown in number. For example, in the decade from 2000, the number of higher-education institutions in Sweden offering programs targeting digital game development grew from 0 to 17 (Berg Marklund 2016).

Game research has expanded enormously in the last 20 years (Martin 2018). The most notable addition is the field of *game studies* (Aarseth 2001). However, this is not the only academic community focusing on games. Several other fields approach games as a first object of study (Deterding 2017). Unfortunately, game research and teaching are not always conducted in an environment that is as interdisciplinary as the industry itself.

Studies of game production reveal that the design and the development of games are different from both traditional IT development (Murphy-Hill et al. 2014) and other media production, such as movies (O'Donnell 2011). Applied game development is deeply interdisciplinary; this poses challenges to academic programs focusing on games, as these are typically conducted in disciplinary contexts.

Project-based learning

Project-based learning has been proposed as a feasible teaching strategy in situations where students need to learn team-based skills such as cooperation and communication. It is also feasible in situations where teaching should provide design experience (Mills et al. 2003). Justified as shifting focus from "what is being taught" to "what is being learned", this teaching approach has, for example, been used in engineering education (Mills et al. 2003) In practice, this means that it should be possible to demonstrate attainment of the learning outcome via the solving of a practical problem or the building of an artefact.

Helle et al. (2006) present an overview of project-based learning and its application in various domains. They refer to Adderley et al. (1975), defining a project method using five aspects (Helle et al. 2006, p. 288):

1. [projects] involve the solution of a problem; often, though not necessarily, set by the student himself [or herself];
2. they involve initiative by the student or group of students, and necessitate a variety of educational activities;
3. they commonly result in an end product (e.g., thesis, report, design plans, computer programme and model);
4. work often goes on for a considerable length of time;
5. teaching staff are involved in an advisory, rather than authoritarian, role at any or all of the stages – initiation, conduct and conclusion.

Helle et al. (2006) argue that at least (1) and (3) are crucial aspects of project-based learning. As an important ingredient in the project-based learning in the present study, we further highlight (5).

Project-based learning has been used in various contexts (including some instances of game development). For example, Sumner et al. (2008) and Goulding (2008) describe a project-based approach to teaching computer science and programming via the development of games. Both approaches are similar to Mills et al. (2003), but lack the interdisciplinarity present in digital game development. Moreover, another important distinction is our focus on game design and game development for the sake of the games themselves, rather than as a vehicle for teaching programming. Estey et al. (2010) used studio-based learning in the context of a (project) course in game development. As they organised groups of students from different disciplines (at least one programmer and one artist per team), their approach was more like ours. Their general course set-up was that all teams first produced a design document for a game. A working game was the second step. The studio-based approach included peer-review of prototype versions. However, their study does not mention play-tests (Estey et al. 2010). Bidarra et al. (2008) describe moving from a game project integrating computer-science topics in one course to a more realistic and interdisciplinary game-development project that included students in game design and development from an art school. They attribute part of the success of their approach to the interdisciplinary organisation. In particular, they highlight the move from focusing only on computer-science-related aspects into projects that, to better mimic the team composition of real-world game developers, integrated game design and artwork/content. Evaluation here included a survey of students' reactions, which included high scores for student satisfaction.

Hogue et al. (2011) describe a similar project-based learning initiative to integrate interdisciplinarity into IT-related studies. The general idea is that, owing to their highly interdisciplinary nature, games are a good vehicle for integration. In the above initiative, the main goal was to integrate students from different specialisations and have them work together in game-development projects. However, the focus was still on the respective, specialisation-specific requirements. For example, one programming goal was that "…the game must contain a basic math library containing vectors and matrix operations" (Hogue et al. 2011, p.126). Our interpretation of the project-based learning approach is that interdisciplinarity should focus on understanding how design decisions in one field affect development in another field. Hence, we feel that the interdisciplinary challenges targeted in Hogue et al. (2011) were not pertaining to game design as such.

Problem and method

The study presented in this article was initiated as a part of a Scandinavian project that aims to understand the Chinese game-development community in a broad sense: to connect with industry as well as universities and organisations that are active in or have an interest in the Chinese game-development community. University teachers with many years of experience of teaching interdisciplinary, project-based courses in game design were among the Scandinavian partners. The Chinese partner had a focus on game development in several educational programs, ranging from art to programming, but had no interdisciplinary modules and no focus on game design.

The course idea was presented to the Chinese partner university as a means to investigate how an interdisciplinary project-based teaching approach is feasible in a context in which people have limited experience of such a method. The Scandinavian researchers took the initiative to test the Scandinavian approach. As the intention was to do something concrete together, the course was planned as such an activity. This field-study approach is motivated by the fact that it is the only way to study a phenomenon holistically and in situ (Lincoln & Guba 1985), which was necessary in our case since we were addressing a multifaceted teaching problem. As an additional consequence of the decision to arrange a course, the Scandinavian researchers set out to analyse their own teaching practice in order to compile the course. This was done through a series of internal workshops that essentially served to compile a longer course into a very condensed two-week version. The results of the workshops were then discussed and adapted in cooperation with the Chinese researcher to form the final course format.

At the planning stage of the course it was decided to conduct a follow-up study on how the concept had worked. Since we aimed to capture a variety of aspects of the teaching situation, we employed an exploratory research approach in a naturalistic teaching environment. Our choice of an explorative approach was motivated by the fact that we wanted to gain better understanding of the challenges associated with using project-based learning in an interdisciplinary context. As revealed in the review of project-based learning in teaching game development, the scale of interdisciplinarity in games can be expected to be challenging when teaching.

Problem

This study analyses an interdisciplinary, project-based approach to teaching game design in a context where courses are taught within traditional disciplines. The research question is focused on the differences between disciplines:

> *How does the perception of a project-based, interdisciplinary course with shared learning objectives differ between disciplines?*

To approach the research question, the following operational sub-questions were formulated:

- What is the self-reported learning outcome?
- How do students perceive the course compared to their regular classes?
- What challenges do students perceive?

The main purpose of these sub-questions is to form a basis for analysing the disciplinary differences. The study is exploratory in nature, but on an abstract level, we hypothesise that there is no difference between art students' and technology students' perceptions of this type of course. There is also an expectation that the self-reported learning will match the defined learning objectives. There is little value in a result that shows that all disciplines experience the course in the same way, but that they do not report any meaningful learning. For the questions related to challenges and difference with regular classes there was no expected outcome.

Method

A mixed-methods research methodology was applied in this study. In mixed-methods research, qualitative and quantitative approaches are combined (Johnson & Onwuegbuzie 2004; Ponce & Pagán-Maldonado 2015). This study has an inductive drive with a sequential design: a qualitative first phase is followed by a quantitative second phase. This corresponds to a *Sequential Mixed Design* according to the classification presented by Teddlie and Tashakkori (2006). The first phase is conducted to inform the second phase. The emphasis in the study (Johnson & Onwuegbuzie 2004) is on the second phase. The complex mix of intercultural and interdisciplinary factors in this study motivated an explorative approach. The combination of qualitative and quantitative perspectives gives a richer picture of a complex object of study.

The data for the first phase was collected during the workshop. It consisted of teacher observations, student reflections and collected student outputs (various prototype versions). Students were asked to report their reflections in an anonymous questionnaire. After each day, four open questions were asked addressing insights, challenges and observations, and also to compare the teaching with their normal classes. In addition to these questions, the teachers made observations during the course and took field notes (using both audio and video recordings). The game prototypes that the students produced were also documented. The material from students and teachers was thematically analysed to produce initial results, along with a number of observations regarding the research questions. These initial results were used as a basis for a follow-up questionnaire for the second, quantitative phase. The questionnaire, which was sent to all participants three weeks after the end of the course, 46 questions with a seven-point Likert scale (Preston & Colman 2000) running from “very low” to “very high”. There were also 21 statements with a seven-point Likert scale running from “strongly disagree” to “strongly agree”. The purpose of this questionnaire was to test the initial results on the whole group of students. The relative strengths of responses enabled comparisons of responses between the different subgroups of students. The prime comparison related to the disciplines involved.

During the introduction to the course, study participants were informed that participation was voluntary. Informed oral and written consent was obtained from all participants. A questionnaire eliciting information on students’ background was distributed on the first day. This included questions not only on previous experience of game development and game-related courses, but also on gaming habits. Students submitted all questionnaire responses anonymously. The questions were asked in Chinese, but the participants were free to respond in either Chinese or English. All Chinese responses were translated into English and the analysis was conducted using the resultant English texts. The statistical analysis was conducted using R version 3.6.0.

Course design

The Scandinavian context

The University of Skövde in Sweden has been offering undergraduate programs in game development since 2002. It has now grown to offer Scandinavia’s broadest and biggest undergraduate programs for game development, including those specialising in programming, game design, game writing, audio, music and art (2D, 3D and animation). The university also offers master’s programs in game development, serious games and user experience. A central element in all programs is a twin focus on interdisciplinary collaboration and project-based learning (Berg Marklund et al. 2014; Engström 2015; Engström et al. 2018). The project-based learning courses have a very strong emphasis on iterative development, prototyping and play-testing.

In 2010, to offer undergraduate programs that combined game development with computer science, multimedia design and communication, Dania Academy in Denmark created a new department: “Dania Games”. All its courses use project-based learning through the HAGI pedagogical model (Lodahl 2015). HAGI is the Danish abbreviation for “action, artefact, transparency and inclusivity”. The academy does not yet offer courses in all the disciplines necessary to produce games. This makes local, interdisciplinary project-based learning difficult. To counter this, a strong tradition of hosting interdisciplinary game production with students from different levels of the Danish educational system has been developed.

The Chinese context

Although China’s game market is the largest in the world (Newzoo 2018), academic game education is still limited. Currently, in 2019, only a few colleges or universities in China have programs in game development as a profession. Students learn game development in relation to professions such as computer science, visual art and graphic design. One major lack is that there is almost no game-design program. Jiangnan University in China offers courses in digital media technology and digital media art. Game development is one of the school’s target areas.

Consequently, it offers courses in game programming and game arts. However, it does not have a course in game design.

Game-programming courses are mostly conducted via standard, classroom teaching. Game art courses (e.g. graphics, character design, environment design and digital painting) are conducted via classroom teaching and workshops. The university is renowned for its food science and production offerings, something we incorporated into the course design.

The Course

In this study, the game-design course was a condensed version of a number of different courses taught in a Scandinavian context. The end goal was for teams to produce a digital game. However, by having students prototype and test their concepts, course design focused on providing an understanding of the second-order design problem.

Designing functional games related to food production was the theme of the course. To the design challenges of entertainment games, functional games add the requirement of meeting a "serious" goal (e.g. teaching).

The course was split across two weeks:

Week 1: Preparation, forming the teams, literature study.

Week 2: A game workshop with a carefully designed structure:

> **Day 1**: Fundamentals of game design; MDA (Hunicke et al. 2004); hands-on analogue assignment (noughts and crosses) for pairs of students; play-testing; introduction to the game engine; functional games and food production; hands-on digital assignment in teams.
>
> **Day 2**: Play-testing of digital assignment; design sessions – generating ideas for several potential games; paper prototyping; examples of functional games.
>
> **Day 3**: Development processes; parallel development – paper prototyping and digital implementation; teachers' play-testing of paper prototypes.
>
> **Day 4**: Digital implementation; teachers' play-testing; preparation for final tests.
>
> **Day 5**: Finalising digital prototypes; teachers' play-testing; final tests with external testers.

The students were recruited and divided into five teams by the collaboration's Chinese teacher. To get to know each other, these teams met in the first week. The students were also provided with two sets of written materials, one concerning functional games development (a translated version of a report from Swedish researchers) and one concerning food production.

Apart from the initial analogue assignment in pairs, students worked in the same teams throughout the second week. With a focus on adding elements of skill and chance, the assignment was devoted to improving the children's game *noughts and crosses* (tic-tac-toe). The first team assignment was implementing a digital noughts and crosses. This was tested in the morning of the second day. The goal of this initial assignment was to have the teams test and reflect on their capacity to produce a digital game of a set design. For the rest of the week, the focus was on the iterative development of a novel digital game. The target was very loosely specified in terms of scope, gameplay and learning. In contrast, the process was structured with a number of checkpoints where prototypes were play-tested.

All digital implementation was via the Unity game engine (Unity Technologies 2019). Most students were familiar with this.

Figure 1. *The classroom during the final play-test session*

The course was held in a classroom (Figure 1) at Jiangnan University's School of Digital Media. This room's flexible arrangement of tables and chairs provided good support for the mix of activities (paper prototyping, digital implementation using laptops and play-testing of analogue and digital games). The program included eight "mini-lectures": 25-minute presentations by the collaboration's Scandinavian teachers. These presentations were given in English with no translation. There were approximately eight hours of activities each day. The final test session was conducted with invited testers who had no prior knowledge of the games or their purpose. One corner of the room was dedicated to Swedish *fika* (a break for coffee and biscuits). *Fika* was deliberately introduced to nurture a relaxed project atmosphere. The mini-lectures were held using portable projector equipment, with the lecturer standing on the floor next to the project teams. These lectures were deliberately kept short, informal and focused on areas on which the teams were currently working.

The course was offered as an extracurricular activity to students at the Jiangnan University. No course credits were awarded. Participating students were given a certificate at the end of the course.

Results

The course had 34 participants. Several food students were occasionally unable to attend due to concurrent activities in their regular classes. Four food students attended fewer than four days of the workshop and were excluded from the final analysis (along with a participant who had erroneous data).

The analysis of the follow-up questionnaire was based on 29 participants, 19 of whom were female. The average age of participants was 22.6. Two participants were specialising in food production (hereinafter referred to as *food*), 14 in media technology/computer science (hereinafter referred to as *technology*) and 13 in media art (hereinafter referred to as *art*). The educational level of participants was a mix of undergraduates (12), postgraduates (7) and alumni (10). Six of the 29 participants missed one day of the workshop. The remaining 23 attended every session.

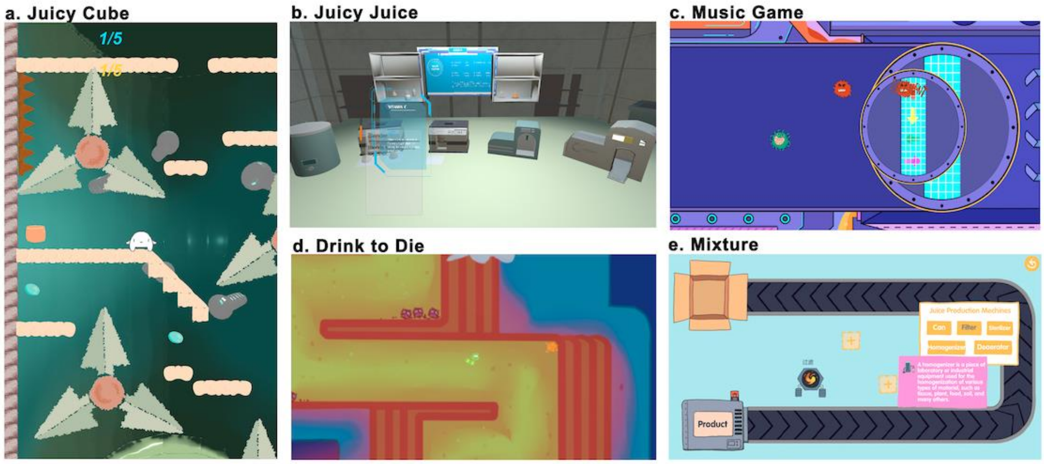

Figure 2. Screenshots from the games produced by the five teams

All participants were game players, and most of them played at least every week. Digital role-playing games were the most commonly mentioned genre. About half of the students, in both technology and art, had taken a Unity course. Self-rated English proficiency (ranked 41st) was higher than self-rated game-design proficiency (45th) and Unity proficiency (46th). This was the case for each subgroup (art, technology and food). All teams worked intensely throughout the workshop week and managed to produce several paper prototypes, of which one was selected to be implemented as a digital game. There was a relatively large variation in the type of games produced, which ranged from platform games to a music game (Figure 2 shows screenshots from the five produced games). All games were tested by external testers. The teachers' perceptions of the course were that it resembled courses conducted in a Scandinavian context. Students followed the same progression curve: great enthusiasm in the early part, a catharsis in the middle and a crunch period at the end. The students worked hard, and most teams appeared to be proud and satisfied at the end. Given the short time frame, the quality of the final games was impressive.

Initial qualitative analysis

An initial analysis was conducted based on the data collected during the course. Along with student responses to open questions, this also included teachers' observations documented in field notes and video clips. The involved teachers conducted the analysis a week after the course had finished. The analysis was made in two stages: first, each teacher individually reviewed student responses and field notes and produced a list of observations; the teachers then met to discuss their observations to produce a common list of strong themes in the material (Table 1).

The themes in Table 1 are arranged under the three sub-questions presented above. The following sub-sections present these themes and give examples of students' comments.

Table 1. Strong themes identified in the initial qualitative analysis of the sub-questions

Learning outcomes	
	The usefulness of paper prototypes.
	Designing noughts and crosses was a valuable experience.
	Testing was an important part of the process.
	The interdisciplinary collaboration was a valuable experience.
Teaching differences	
	Focus on applied.
	Active student participation. Interdisciplinary teams.
	Open atmosphere.
	The teacher role.
Challenges	
	The English language was an obstacle. Not everyone understood lectures.
	The use of Unity was found to be challenging.
	The functional games element was found hard to include and test.

Learning outcomes

After each day of the workshop students were asked to answer four open questions. The learning was covered mainly by the questions “What did you find interesting yesterday?” and “What did you find to be the important concepts yesterday and what insights did you gain about them?”.

Several students highlighted the value of working with paper prototypes:

> *Hands-on paper models let us jump away from the sky; many practical production problems can only be discovered by hands-on experience. (art student)*
>
> *The game concept on paper is very important. (technology student)*

In particular, students commented on the initial assignment to improve noughts and crosses:

> *The modification of a prototype game from noughts and crosses allows students to quickly integrate into the understanding of the nature of the game, breaking our traditional perception of game design and broadening the dimensions of thinking. (art student)*

Testing is a central element of game development (Lé et al. 2013; Kasurinen & Smolander 2014) and essential for understanding the effects of the game design. This was also reflected in students’ comments:

> *During the testing phase, we found that the problems were much more than we thought. (art student)*
>
> *In the testing session, it is really difficult for the player to play the game as the game designer envisions. (technology student)*

The insights regarding paper prototypes and testing are important, as they indicate that students experienced true facets of game design. Another such aspect is the importance of interdisciplinary collaboration. Several students expressed this clearly in the open questions:

> *For the first time, I really cooperated with art students. There is a feeling that I have opened the door to the art world. I like this kind of discussion. (technology student)*

> *Very interesting learning style to communicate programming and art together. (technology student)*

However, there were also some remarks concerning communication difficulties:

> *Because I don't understand what programmers want and don't understand their way of thinking, which leads to some communication barriers. (art student)*

This is not necessarily a negative experience. Communication between art and technology disciplines has some inherent challenges. This has, for example, been reported in studies of game companies (Marklund et al. 2019). The exposure to this schism in an educational context can be valuable preparation for a future professional career in games.

Teaching differences

The open questions asked after each day included one focused on teaching differences: "What are your reflections on working like you did yesterday compared to your normal classes?" Examples of student comments include:

> *I feel that yesterday's understanding of the game by letting us improve the noughts and crosses is more conducive to our thinking and communication. Unfortunately, we usually tend to receive the teacher's knowledge when we go to class, which is rather boring. (art student)*

> *This form is more open and active, emphasising autonomous learning. (technology student)*

The strongest themes in these comments are the focus on applied problems and active student participation. The open specification of the tasks in the course allowed for great variation in the resultant games. This was highlighted in one of the student's comments:

> *I also like the feeling of different outcomes between different groups facing the same theme. This allows me to understand how different people think. (art student)*

Many students highlighted collaboration in interdisciplinary teams:

> *Students can freely create and discuss together. In the usual study, we often have no time to discuss and communicate together frequently, which leads to the gap between art and programming, and they don't understand or even contradict each other. (technology student)*

Students express that they experienced a more open atmosphere and that there was a difference in the role of teachers:

> *Usually teaching and practical operation separation, teachers and students have a great sense of distance. (technology student)*

> *The teacher doesn't usually give so much time for discussion and cooperation, usually in class. (art student)*

Challenges

The analysis of challenges was based on both on teacher observations and response to the daily question "What did you find difficult yesterday?" One thing that emerged from the observations during the course was that students found game creation challenging. Despite this challenge, it appears that students were satisfied with what they accomplished and their team's success. These are examples of some comments from students:

> *Today is the end day. I found that everyone's games are almost finished in such a short period time and they are very polished. A real game test was conducted. (technology student)*
>
> *…I feel that after completing a game, I have a sense of accomplishment. It is also very interesting to try others' games. (art student)*

The most apparent challenge, which we had also anticipated, was related to language. All communication between teachers and students was in English, a second language to all involved. It is clear that the level of English poses a challenge to learning. One student commented:

> *The Swedish teacher speaks English all the time, I don't quite understand it. (technology student)*

Another observation consistent between teachers was the challenge the Unity engine posed to most students. Four teams sufficiently completed the initial digital assignment, but none excelled. Students also repeatedly mentioned their difficulties in understanding Unity:

> *It's still a character animation problem, and it's about the same as yesterday. Later, the program can be optimized, but the actual effect is still not ideal. I don't understand where the problem lies. (art student)*
>
> *Still not understanding the use of Unity. (technology student)*

Incorporating the functional (serious) game element into the game was a third challenge identified in the initial analysis. All teams managed to deliver a game, and testers appreciated most of the games. The potential of these games to be used as learning games was not formally evaluated. The teachers' analysis after the course indicates that the functional elements had been incorporated at a very shallow level. Food production was represented as a theme in the games, but it was not integrated into the gameplay.

Quantitative analysis

The results of the initial analysis were used as a basis for the questionnaire distributed to participants three weeks after the course. The group-wise comparison is based solely on the questionnaire data.

All questions were answered on a positively ordered, seven-point Likert scale. It is difficult to draw conclusions from the absolute values, but a relative comparison can give some indications. The 46 questions were sorted according to their average score, and each question's ranking was used as an indication of the strength of the statement. Appendix A gives the complete set of questions, sorted on total rank; it also shows each question's rank within the subgroups formed by art and technology students. The same rank data is visualised in the scatter plot in Figure 3. Each point in the figure corresponds to the rank for the question in the art (x-axis) and technology (y-axis) subgroups. The number above a point is that question's overall rank. It should be noted that the comparison between disciplines is between the art and technology students. There were only two students with a food-production background; their responses were excluded from the groupwise comparison.

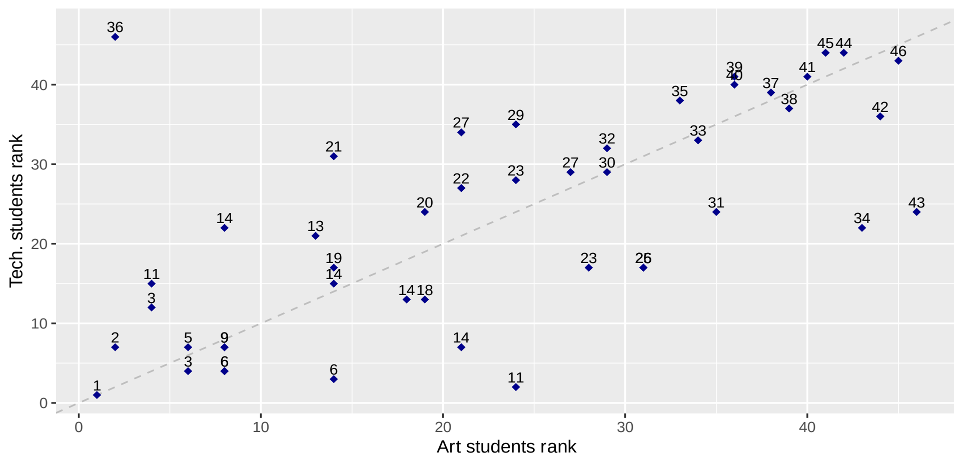

Figure 3.Correlation between art and technology in ranking of questions (the number above a point represents the total rank of that question)

Figure 4 shows corresponding data for the 21 statements in the questionnaire. The detailed data is shown in Appendix B.

Overall, the art and technology students ranked the questions and the statements very similarly. The scatter plot of questions in Figure 3 shows a clear linear pattern, despite some noise. For example, the point labelled 36 in in the top left corner is a clear outlier. This question has a total rank of 36, and from the table in Appendix A it is possible to infer that the question relates to the respondees' contribution to art. Hence it is natural that the rank is high in the art group (ranked 2nd) and low in the technology group (ranked 46th). The correlation between art and technology has been tested using Kendall's tau$_b$ rank (Arndt et al. 1999). This test shows that there is a statistically significant positive correlation ($\tau_b = 0.52$, $p < 0.001$) between art and technology students. This means that the alternative hypothesis, that there is a difference between how the groups responded to questions, can be rejected.

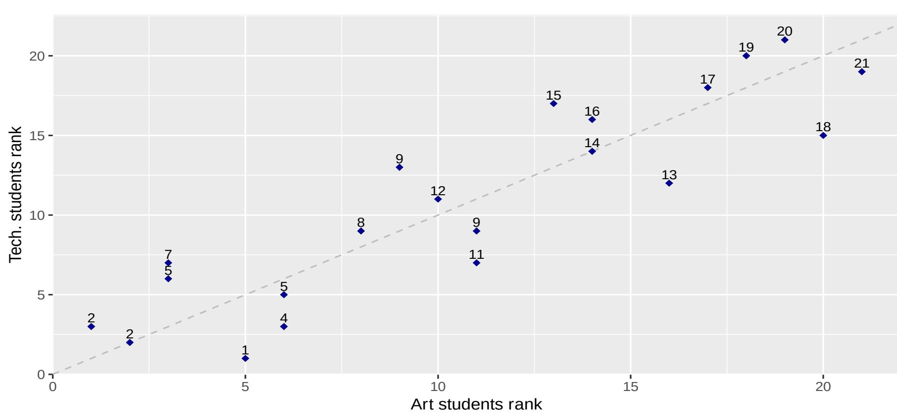

Figure 4. Correlation between art and technology in ranking of statements (the number above a point represents the total rank of that statement)

The statements in Figure 4 show a clear linear pattern in which the points are close to the centre line. There is a very significant positive correlation ($\tau_b = 0.71$, $p < 0.001$) between art and technology students. This means that the alternative hypothesis, that there is a difference between how the groups responded to statements, can be rejected.

The following sections analyse responses to individual questions to test the observations made in the qualitative analysis.

Learning outcome

The questionnaire had eight questions addressing self-reported learning in different areas. None of these questions features in the highest-ranked questions, but three appear in the upper half. These three relate to: increased understanding of functional games; game testing (both ranked 14th); and game design (ranked 18th). The remaining five questions are in the lower half: game art (29th); game programming (35th); English (37th); food production (39th); and Unity (42nd). The absolute merits of these ranks are hard to evaluate, but it is clear that the order of the areas was aligned with the course's goals. It is interesting to note that although students used Unity to produce the final digital game, they reported the lowest learning for the program. This indicates that there was a successful focus on game design rather than on digital implementation. One question addressing the general learning value of the workshop was ranked 14th. The answers to this question showed a notable difference between art (8th) and technology (22nd). There was only a small difference between the groups for the answers to the other learning-related questions, although there was a tendency for the art group to rank more highly in most areas.

Nine questions had a particular focus on elements that contributed to the understanding of game design. As shown in Appendix A, three elements identified in the initial analysis (*paper prototypes*, *testing* and *noughts and crosses*) were all ranked highly (1st, 6th and 11th, respectively). Both art and technology students found prototypes and testing to be valuable. There was a notable difference between disciplines in how they perceived the initial noughts and crosses assignments. The art students appeared to value it much more (4th) than did the technology students (15th). The same pattern applied to interdisciplinary collaboration, which art students ranked higher than did technology students. During the course the teachers observed that many art students had very vague conceptions of how their art was used in games. For example, many students thought that character animation should not include character translation (which, based on user input, is handled in the game engine). After one of the course days, an art student commented:

> *I need to give the programmer all the elements needed for the game UI interface, and put all the decompositions into png format and hand them to the programmer. (art student)*

It is possible that interaction with art students did not give rise to such fundamental insights for the technology students. The technology students reported that they learned more from their teachers' supervision as they solved challenges related to the implementation of game design. The importance of one-to-one interaction with teachers ranked 2nd for technology students, but 24th for art students. A potential explanation of this is the large challenge presented by Unity (and faced mainly by technology students). None of the involved teachers had any specialisation in art, so there was no basis for art students to initiate art-related discussions.

All but one of the remaining six elements appeared in the top half of the ranking: *one-to-one interaction with teachers* (11th), *one-to-one interaction with other students* (14th), *team work* (18th), *collaboration with other disciplines* (21st), *written material* (23rd) and *lectures* (26th). Traditional teaching methods – *written material* and *lectures* – were the elements with the lowest perceived contribution to the understanding of game design. This is not surprising (Bligh 1998), considering the non-interactive nature of these methods. A difference between groups can be observed here, however: ythe technology group ranked lectures higher (17th) than did the art group (31st).

The questionnaire contained a section for students to rate their contributions to their team's work in the aspects of idea generation, game design, programming, art, audio, project planning and testing. The only notable differences between the art and technology students were with respect to contributions to programming and art. The technology students ranked their contribution to art the lowest, and the art students ranked their contribution to programming the lowest. However, for the course's main topic, game design, both groups scored similarly: 21st for art students and 27th for technology students. The same applied to idea generation (19th and 24th, respectively) and testing (34th and 33rd, respectively). This indicates that the different disciplines shared responsibility for the most central elements of the course.

Teaching differences

The questionnaires revealed a difference between the course and traditional teaching. The questionnaire's three questions regarding differences with respect to traditional teaching were ranked 3rd and 6th highest, with high ratings indicating that students perceived the workshop to be different from traditional teaching. The other two questions examined whether students perceived that they were more active, and if the atmosphere was more relaxed. There was only one notable difference between the groups with regards to this: the technology students ranked this question ranked 3rd; the art students ranked it 14th. This may reflect the latter's greater focus on workshops in their regular classes.

Challenges

One thing that is clear from the statements (Appendix B) is that students in both groups found game creation challenging (ranked 2nd). Despite this, the ranking suggests that students were satisfied with what they accomplished (ranked 5th) and their team's success (ranked 9th). This was consistent between groups.

The initial analysis regarding problems with Unity was partly confirmed by the questionnaire. The students' prior Unity knowledge was the lowest-ranked question, but the challenges with Unity were also ranked relatively low (38th of 46). There was no difference between groups with respect to this. There was, however, a difference in how much students enjoyed using Unity" the rank in the technology group (22nd) was clearly higher than in the art group (43rd). To analyse the role of Unity knowledge, self-reported learning was analysed group-wise for the group with high self-rated Unity knowledge (answers ranging from 5 to 7, $n = 6$) and the group with low self-rated knowledge (answers ranging from 1 to 3, $n = 17$). The results showed no clear difference between the groups, although there were minor differences in both directions. The biggest difference was for the question "To what degree did the workshop give you increased understanding of programming?" Here, the high Unity knowledge group's average score was 1.11 above that of the other group. However, the difference was not statistically significant ($p = 0.271$). This indicates that the challenges with Unity were not as severe as suspected in the initial analysis and, most importantly, that they did not have a negative impact on the learning outcomes for the central elements of the course. The challenges with English were not apparent from the results of the explicit questions. "To what degree did language barriers have a negative impact on the learning?" ranked 40th out of the 46 questions. Self-rated English proficiency was low (41st), but still higher than both prior Unity knowledge (46th) and game-design knowledge (45th). To analyse the impact of English knowledge, a group-wise comparison was made in the same manner as for Unity. The comparison revealed a clear language effect. Compared to the group with high English proficiency (n = 8), the group with low English proficiency (n = 14) had lower self-reported learning in all course aspects. The total average for all questions related to learning outcome was 4.25 for the group with low English proficiency and 5.27 for those with high English proficiency. This was a statistically significant difference ($p = 0.011$). It is clear that the level of English poses a challenge to learning. This is not a surprising result, but it is included here as it indicates that the questionnaire instrument was sensitive enough to capture it.

Incorporating the functional (serious) game element into the game was the third challenge identified in the initial analysis. The results related to functional games all appeared in the middle of the ranking. Thus, there was no strong indication that students perceived it as problematic. The challenges with functional games were most likely something the teachers concluded from observations.

General observations

A general observation regarding the difference between the art and technology groups was the distribution of scores. The average score on all questions for art students was 5.20. For technology students it was 4.82. In addition, the art students had a majority of their responses at the extreme values (1, 2, 6 and 7), while the technology students had a majority of responses at the middle values (3, 4 and 5). This comparison was based on the ranking differences, which was intended to even out potential differences in how the groups approached Likert-scale answers.

Limitations

The current study is small in scope in terms of the duration of the course and the number of participants. It does not meet established standards for controlled, evidence-based, quantitative studies of learning that address long-term effects and transfer. The quality of this study lies in its richness: there is a strong element of interdisciplinary collaboration; the context is intercultural; the subject area is focused on creativity and experience; and, the area is new, with limited previous research. This study aggregates many years of experience of teaching game design, and shows that it is applicable in a different interdisciplinary, cultural context. A mixed-methods research design is deliberately chosen to explore this complex phenomenon. Assessing the validity of mixed-methods research is particularly complex (Onwuegbuzie & Johnson 2006, p. 48), as it “involves combining complementary strengths and nonoverlapping weaknesses of quantitative and qualitative research”. The qualitative first phase informs the second quantitative phase. This can be seen as a triangulation (Ponce & Pagán-Maldonado 2015) of the result that improves the validity of the study. In addition, steps to ensure the internal validity of each phase have been taken according to the traditions of the corresponding paradigm. In the qualitative phase, this included (Tracy 2010) the combination of several data sources and the combined observations and analysis of several researchers. In the quantitative phase we applied standardised statistical tools to test the observations made.

Some important factors limit the inference transferability (external validity) (Teddlie & Tashakkori 2003) of the presented results. As the course in China was provided as an extracurricular activity with no assessment or grading, it differed from a regular course. The students volunteered to participate and were most likely highly motivated to study the topic. Teacher-student ratio, which was very high in this course, was another difference from regular classes. Finally, some statistical tests were based on assumptions that cannot be guaranteed. All this demands caution in drawing conclusions from the presented results.

Discussion and conclusions

A central element in project-based learning for traditional engineering disciplines (including software engineering) is that it should involve solving a problem (Helle et al. 2006). This is not the main goal of a game, which instead is intended to create an experience. Games cannot be approached in the same way as regular software (Murphy-Hill et al. 2014) or traditional media (O'Donnell 2011). The second-order design problem (Salen & Zimmerman 2004) is fundamental to games. This affects how game projects are conducted in both industry and research (Berg Marklund et al. 2019; Eladhari & Ollila 2012). The study in this article indicates that, via a highly condensed, interdisciplinary project-based learning module, it is possible for both art and technology students who have no prior game-design training to understand these implications. Hence, our focus on the shared learning objective stands out compared to other interdisciplinary initiatives to teach game development, such as Hogue et al. (2011) and Bidarra et al. (2008). These largely focus on the different disciplines and their contributions, rather than on the game-design task itself.

Similar to Bidarra et al. (2008), our study shows high scores in student satisfaction, and, in terms of artefacts produced, successful projects. However, Bidarra et al. (2008) found that when students were asked to indicate the areas in which they had improved the most, they mentioned media and programming techniques. Creative work seems to have been left to game-design students. Our study indicates that game design can be presented as a creative exercise for students of different backgrounds. In fact, it was a very challenging aspect of our study that the shared learning objective lay outside the core of the different subgroups' individual areas of expertise. The self-reported learning and contributions to each team's work were very similar for the two major groups (technology and art students). Both groups reported a similarly high contribution to core elements such as ideation, game design and testing. The course elements that contributed most to learning were the use of paper prototypes (Eladhari & Ollila 2012) and the test sessions. This corresponds very well with the learning objectives related to the second-order design problem. This study shows that deeply interdisciplinary project-based courses with shared learning objectives can successfully be conducted even in a context where participants have no prior experience of such approaches. The inference transferability of the results presented in this study is strengthened by the fact that it is based on many years of teaching similar courses. The course concept developed as part of this work has moreover been repeated successfully several times since this study in both China and Scandinavia.

Compared to a typical Scandinavian game-development class, the Chinese context of this study differed in its ratio of female to male students. In both the technology student group and the art student group, females were in the majority. In Scandinavia, technology groups are typically predominantly male (Stoet & Geary 2018). It is not clear if the Chinese groups were representative of the larger student population, or if the Chinese game industry also reflects this gender balance. However, it is an interesting area for future studies.

The present study suggests that it is possible to teach core game-design principles in a very short time. This is not to say that the course resulted in games with new or exceptional gameplay. It takes much more than a two-week course to become a good game designer. The important goal of this course was to get students to understand the fundamental principles of game design. Evidence that this was successful for at least one student, was reflected in this response in one of the daily questionnaires: “In the testing session, it is really difficult for the player to play the game as the game designer envisions.”

This study’s results have clear implications for the teaching of game development. It may also be relevant for other deeply interdisciplinary areas, such as architecture (Li et al. 2015), industrial design (Fixson 2009) and theatre studies (Pavis 2001), where central learning objectives are shared across disciplines.

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Compliance with ethical standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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Appendices

These appendices list all the questionnaire's Likert-scale questions (Appendix A) and statements (Appendix B), sorted on the average score for the whole group. The first column shows the total rank for the question/statement. The rightmost columns show the corresponding rank for the subgroups with only art (n=13) and technology (n=14) students, respectively.

Appendix A. Questions

Tot. rank	To what degree...	Avg. score	Art rank	Tech. rank
1	...did the work with paper prototypes contribute to the understanding of game design?	6.17	1	1
2	...did you find it valuable to work together with students from other disciplines?	5.93	2	7
3	...did you find the workshop different from traditional teaching?	5.86	6	4
3	...did the collaboration with other disciplines lead to new insights?	5.86	4	12
5	...are you proud of the work your team accomplished?	5.83	6	7
6	...did the test sessions contribute to the understanding of game design?	5.79	8	4
6	...were you more active in this workshop compared to traditional teaching?	5.79	14	3
6	...was the atmosphere more relaxed in this workshop compared to traditional teaching?	5.79	8	4
9	...did you enjoy participating in the workshop?	5.72	8	7
9	...do you think your team was a successful team?	5.72	8	7
11	...did the initial noughts and crosses assignments contribute to the understanding of game design?	5.69	4	15
11	...did the one-to-one interaction with teachers contribute to the understanding of game design?	5.69	24	2
13	...did your team collaborate efficiently?	5.55	13	21
14	...did you find the workshop valuable for your learning?	5.52	8	22
14	...did the workshop give you increased understanding of functional games?	5.52	14	15
14	...did the workshop give you increased understanding of game testing?	5.52	18	13
14	...did the one-to-one interaction with other students contribute to the understanding of game design?	5.52	21	7
18	...did the team work contribute to the understanding of game design?	5.48	19	13
19	...did the workshop give you increased understanding of game design?	5.38	14	17
20	...did you contribute to your team's work on idea generation?	5.28	19	24

Tot. rank	To what degree…	Avg. score	Art rank	Tech. rank
21	…did the collaboration with other disciplines contribute to the understanding of game design?	5.24	14	31
22	…did you contribute to your team's work on game design?	5.17	21	27
23	…did the written material contribute to the understanding of game design?	5.14	24	28
23	…did the one-to-one interaction with teachers help overcome technical challenges?	5.14	28	17
25	…did the one-to-one interaction with teachers help overcome game design challenges?	5.10	31	17
26	…did the lectures contribute to the understanding of game design?	5.07	31	17
27	…do you rank your game design knowledge after the workshop?	4.97	27	29
27	…did your team manage to create a functional game?	4.97	21	34
29	…did the workshop give you increased understanding of game art?	4.93	24	35
30	…do you rank your functional game design knowledge after the workshop?	4.90	29	29
31	…did you understand the English spoken by teachers?	4.83	35	24
32	…did you contribute to your team's work on project planning?	4.79	29	32
33	…did you contribute to your team's work on testing?	4.72	34	33
34	…did you enjoy using Unity?	4.50	43	22
35	…did the workshop give you increased understanding of game programming?	4.38	33	38
36	…did you contribute to your team's work on art?	4.34	2	46
37	…did the workshop give you increased understanding of English?	4.21	38	39
38	…did you experience challenges when using Unity?	4.08	39	37
39	…did the workshop give you increased understanding of food production?	4.07	36	41
40	…did language barriers have a negative impact on the learning?	3.97	36	40
41	…do you rank your English skills?	3.79	40	41
42	…did the workshop give you increased understanding of Unity?	3.69	44	36
43	…did you contribute to your team's work on programming?	3.52	46	24
44	…did you contribute to your team's work on audio?	3.38	42	44
45	…do you rank your prior game design knowledge?	3.24	41	44
46	…do you rank your prior Unity knowledge?	2.97	45	43

Appendix B. Statements

Tot. rank	Statement	Avg. score	Art rank	Tech. rank
1	Active student participation increases learning!	6.21	5	1
2	It was challenging to produce a fun game!	6.17	1	3
2	It was challenging to produce a functional game!	6.17	2	2
4	The workshop format of teaching makes students more active than in normal class room teaching!	6.03	6	3
5	I joined the workshop because I wanted to learn more about game design!	5.93	3	6
5	I think this form of teaching has a potential to be used more in other classes!	5.93	6	5
7	Mixing students from different disciplines increases learning!	5.90	3	7
8	I would have appreciated more guidance from teachers!	5.59	8	9
9	I joined the workshop because I wanted to learn more about functional games!	5.45	9	13
9	My team managed to create a fun game!	5.45	11	9
11	I think the teachers communicated the goals of the workshop clearly!	5.38	11	7
12	The workload in this workshop was higher than in regular classes!	5.34	10	11
13	I would have preferred to work more like this in my prior Unity course!	4.95	16	12
14	I would preferred to focus more on my area of expertise!	4.66	14	14
15	My team had a good representation of food production elements in our game!	4.59	13	17
16	The lunch breaks were too short!	4.38	14	16
17	The workload in this workshop was too high!	3.79	17	18
18	My prior knowledge of Unity was applicable in the prototyping!	3.77	20	15
19	I prefer to spend more time reading than working with applied problems!	3.10	18	20
20	The way I used Unity in this workshop was different to my prior use of it!	2.87	19	21
21	I think the instructions from teachers were too unclear!	2.83	21	19