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To play or not to play: on the motivational effects of games in engineering education

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ABSTRACT
The popularity of games as educational tools has steadily increased and is mainly explained by the motivational power that is ascribed to games in general. The research investigates the role of different motivational forms in educational gaming and the influence of game and teaching context on the students' motivation to involve in game play. Based on self-determination theory and a mixed-method case study approach, seven educational games played in a postgraduate level engineering course in two consecutive years were studied. Our research reveals that different motivational forms can co-exist when students play games and that the interplay of game attractiveness, game learning and game operativeness can explain the emergence of these motivational forms.

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Educational game; motivational effects; self-determination theory; mixed-method approach

1. Introduction

The use of games as educational tools has gained increased interest over the last decennia in many engineering fields including software engineering (Maxim et al. 2016; Valle et al. 2017; Calderón et al. 2018), mechanical engineering (Braghirolli et al. 2016; Chang et al. 2016; Mavromihales, Holmes, and Racasan 2019), civil engineering (Alanne 2016; Oo and Lim 2016; Taillandier and Adam 2018) and electrical engineering (Callaghan et al. 2015; Bahadoorsingh, Dyer, and Sharma 2016; Padilla et al. 2016). Referred to as educational games, their primary purpose is to educate and train the player, which differentiates them from pure entertainment games. The entertaining quality of games is rather used as a vehicle to support learning. The rapid popularity of games in learning environments can be related to the widespread movement from teacher-centred to learner-centred approaches in education, advanced ICT developments for more realistic simulations and user-friendly interfaces, and a growing group of younger learners for whom computer games in particular are engaging activities (Blanco et al. 2012; Guillén-Nieto and Aleson-Carbonell 2012; Arnab et al. 2015). In this regard, games have been proposed as valuable tools for engineering education since they promise to activate students to take ownership of their learning process by accommodating knowledge co-creation and different learning styles and paces (Baker, Navarro, and Van Der Hoek 2005). They are also intended to foster experiential learning by allowing students to experience the effectiveness of their decision-making and problem-solving in a simulated real-life environment (Lee, Lau, and Ning 2006). Game characteristics such as control, challenge, competition and interaction are seen as the motivational drivers to

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keep students engaged in playing a game and thus learning (Kirriemuir and Mcfarlane 2004; Boyle, Connolly, and Hainey 2011).

The promise of engaging and motivating students through games seems particularly important for engineering programmes with their more traditional transmission classroom environments that become less attractive for students but also fall short of allowing the development of skills such as system thinking, team working, communication and creativity (Bodnar et al. 2016; Despeisse 2018; McBurnett et al. 2018). Based on a review of games developed in different engineering disciplines, Deshpande and Huang (2011) conclude that 'the shift from traditional lecture-based education to simulation games-based education is gradual and still not widespread' (408). They recommend more research on assessing the relationship between student learning and game use including appropriate metrics for game effectiveness. The results of the recent literature review conducted by Bodnar et al. (2016) on the implementation of games to teach undergraduate engineering students point in the same direction. Although the review finds consensus among engineering educators that games are useful learning tools, it also identifies weaknesses of previous studies on game applications in terms of validated quantitative and qualitative effects on student learning. The studies 'nearly unanimously agree that students enjoy game-based learning' (160) without providing a methodically sound and theoretically underpinned assessment of the motivational aspects for students' engagement in game play. Despite methodical and theoretical shortcomings, the almost completely positive results reported can give the biased impression of games being unconditionally motivating (Despeisse 2018).

Insights from other educational domains suggest a more differentiated picture of the motivational and learning effects of games. For example, the reviews of Wouters, Van der Spek, and Van Oostendorp (2009; Wouters et al., 2013) cannot find convincing evidence for the motivational pull of games in education and reveal that educational games are not more motivating than other instructional methods. It seems that the motivational appeal of games as demonstrated for entertaining computer games (Ryan, Rigby, and Przybylski 2006; Przybylski, Rigby, and Ryan 2010) does not fully play out in the educational context. For Wouters et al. (2013) the presence of different motivational forms are responsible for students' involvement in playing educational games. Intrinsic and extrinsic types of motivation can co-exist in the educational context (Hartnett, George, and Dron 2011). In this sense, games should not be regarded as educational practices that intrinsically motivate students by default (Iten and Petko 2016) but may require forms of extrinsic motivation for students to become involved and its further internalisation for sustained involvement. Which motivational form is activated will depend on the extent to which games are attractive to students and support students' learning; the variety of possible game designs and mechanics will have different motivational effects (Proulx, Romero, and Arnab 2017). In addition, through the integration of games in the classroom, a number of factors come into play that can interfere with the motivational effects of games including the learning situation, the teacher and the learning style of students (Molin 2017; Proulx, Romero, and Arnab 2017).

The aim of this research is to enhance our understanding of the motivational effects of games in engineering education and their contextual emergence by answering two questions: (i) To which extent do different motivational forms play a role for the involvement of engineering students in educational games? and (ii) How does a game and its teaching context influence students' motivation to involve in game play? With the well-established theoretical lens of Self-Determination Theory (SDT), we investigate the motivation of students playing seven different games in a postgraduate level course of a Civil Engineering and Management programme in two consecutive years. By adopting a mixed-method research approach combining observation, focus groups and surveys, we will obtain more fine-grained insights into the motivational nature of educational games in engineering and go beyond the mere focus of previous studies on games themselves. We will particularly show that different motivational forms can co-exist in game play and that the emergence of these forms can be explained by the interplay between game operativeness, game attractiveness and game learning. Here, the teaching and classroom context plays a critical role for the extent to which students experience a game as being attractive and instructive, and, thus, remain motivated to further engage with game play.

The paper begins by introducing self-determination theory and its potential for explaining motivation in the educational context, followed by the motivational aspects of games previous research has identified. We then explain our research approach before we present the results of the seven game cases investigated. In the next section we discuss our findings in the light of the extant literature on motivation in game play. We finish the paper with a short conclusion section.

2. Conceptual background

2.1. Self-determination theory and students' learning

As with any other instructional method or tool, educational games should be able to motivate students to get involved in learning activities. Although it is easy to describe motivated students, it appears much harder to find and create them (Garris, Ahlers, and Driskell 2002). Research has addressed this issue and tried to better understand, in general, the willingness of individuals to engage in an activity and, in particular, the motivation of students to learn. A theory that has proven useful in explaining the motivational forces of students to learn is self-determination theory (SDT) (Ryan and Deci 2000; Deci and Ryan 2008).

A main focus of SDT has been the type of motivation that prompts individuals to engage in particular activities with the central argument that this engagement is based on the intrinsic needs of humans for competence (sense of efficacy and mastery), relatedness (social connectedness) and autonomy (sense of agency and control) (Deci et al. 1991). Intrinsically motivating activities are seen as the natural fundaments for learning, and intrinsically motivated students engage in such activities because they are challenging, enjoyable and satisfying to do (Noels et al. 2000; Vansteenkiste, Lens, and Deci 2006). The activities are pursued for their own sake and do not need outside incentives. It has been shown that autonomy-oriented classroom environments are conducive to the intrinsic motivation of students, whereas externally controlled activities prevent the emergence of intrinsic motivation (Niemiec and Ryan 2009).

However, not all educational programmes and courses are immediately perceived as inherently enjoyable by students and require other incentives for students to get involved. External motivation refers to such situations in which the reasons for undertaking an activity are separate from the activity itself (Deci and Ryan 2008). The activity becomes instrumental to an end. This may include getting a good grade or passing a course. Externally motivated behaviour does not necessarily mean that any form of self-determination is lacking. SDT distinguishes different types of extrinsic motivation that vary in the extent to which the associated activities are perceived as autonomous and externally controlled and initially externally regulated behaviour becomes internalised (Vansteenkiste, Lens, and Deci 2006; Niemiec and Ryan 2009). External regulation is the least autonomous form of extrinsic motivation and refers to behaviour that is responsive to external contingencies such as punishments or rewards and cannot be maintained once the controlling contingencies are removed. Introjected regulation is related to behaviour originating from internal pressure that individuals have incorporated into the self, such as self-aggrandisement or avoidance of guilt (Noels et al. 2000). Although the pressure resides inside the person, the behaviour is not regarded as self-determined since it does not result from personal choice. A greater degree of autonomy is reached with identified regulation. Here, an individual recognises the personal value and importance of an activity and, thus, pursues the activity more willingly. The most autonomous form of extrinsic motivation is integrated regulation where identified regulations have been integrated in the individual's sense of self. The activity is still personally valuable due to an expected outcome but is more aligned with an individual's other needs, values and identities (Deci et al. 1991). In situations where individuals do not see any relationship between their activities and the consequences of those activities, they are neither externally nor internally motivated. This lack of motivation or amotivation will prompt individuals to stop doing the activity.

From the perspective of SDT, enhanced learning is associated with more autonomous forms of extrinsic motivation, and addressing students' basic psychological needs for autonomy, competence and relatedness facilitates the internalisation of their motivation to learn (Niemiec and Ryan 2009).

2.2. Games and motivation

Motivation in game playing has been mainly associated with intrinsic motivation. Games are often assumed to possess an inherent motivational power through which individuals become immersed and absorbed in a game and experience the game play as enjoyable. Indeed, previous research has shown that particularly players of entertaining games engage and persist in game play because of satisfying their psychological needs for autonomy, competence and relatedness (Ryan, Rigby, and Przybylski 2006; Przybylski, Rigby, and Ryan 2010; Neys, Jansz, and Tan 2014). This engaging potential of games is brought forward to argue that games are also suitable in the educational context (Erhel and Jamet 2013) and in engineering education (Bodnar et al. 2016). However, if games go beyond pure entertainment and become serious, they are purposefully developed and applied as instructional tools to transfer learning content with the aim of educating and training the player (Blumberg et al. 2013). As being part of an educational programme or course, games cannot be expected to motivate students simply because they are used (Proulx, Romero, and Arnab 2017). For example, Leemkuil et al. (2003) report on the pilot application of a knowledge management simulation game and showed that functionality problems and complexity can lead to dissatisfaction and that challenging, competitive and collaborative games are valued by players.

If we follow Garris, Ahlers, and Driskell (2002), who describe educational game play as a motivational process in which repeated cycles of judgement (interest, enjoyment, task involvement and confidence), behaviour (persistent re-engagement) and feedback (progress towards goals) are triggered, we suggest that students may require externally regulated incentives to be motivated to get involved in a game and to stay motivated to further engage in game play. We do not deny the potential of educational games to intrinsically motivate students, but we advocate a more differentiated view including other motivational forms as well and addressing the reasons for their emergence in the teaching environment of game use. Frank (2007) and Westera (2017) argue that an effective design for educational games has to attain and balance three goals: (i) the provision of an engaging game, (ii) the link of game content with learning goals and (iii) the consideration of the context of game use. Based on this argument and the extant literature, three factors possibly triggering and sustaining the motivation of students in game play are proposed: (i) game attractiveness, (ii) game learning and (iii) game operativeness.

The vast majority of scholars relate the appeal of games to their characteristics. As there is no common agreement on the defining characteristics of games (Boyle, Connolly, and Hainey 2011; Wouters et al. 2013), there is also no shared view on motivation-stimulating characteristics. For example, Garris, Ahlers, and Driskell (2002) see six game characteristics as primary determinants of motivation: fantasy, rules/goals, sensory stimuli, challenge, mystery and control. Amory (2007) identifies four motivational aspects: play, exploration, challenges and engagement. For Blumberg et al. (2013), immersion, identity, interactivity, agency, challenge, narrative and feedback are characteristics for attracting and maintaining the interest of players in a game. Despite the differences in motivating game characteristics, there are commonalities among authors that can be best described as the attractiveness of a game and include characteristics such as challenge and engagement. It is expected that these characteristics will act as motivating stimuli for engineering students to get involved as well as stay involved in game play.

A particular challenge for educational games lies in the need of blending the game design with the learning to be achieved with the game. On the one hand, simplified game designs or overemphasised learning content can make games less challenging and enjoyable (Malliarakis et al. 2015;

Oo and Lim 2016). On the other hand, more complex game designs offer different possible trajectories and narratives a player can follow, which may lead to different game experiences and, thus, different learning outcomes (Leemkuil et al. 2003; Westera 2017). In addition, games are typically implemented as part of a broader educational programme or course, and their design should be aligned with the overall goals of these programmes or courses (Bahadoorsingh, Dyer, and Sharma 2016; Oo and Lim 2016; McConville et al. 2017). Using games in an ad hoc manner for an educational purpose without the incorporation of sound instructional principles will diminish envisaged learning (Gunter, Kenny, and Vick 2006). A basic principle to facilitate learning from game play is the provision of feedback to the player. Feedback is seen to be critical for regulating game flow and sustaining interest in the game (Leemkuil et al. 2003; Philpot et al. 2005; Liao et al. 2011). It can be directly integrated into the game play to give information about the progress towards the goals of the game, for example through rewards. It can also be provided as debriefing at the end of the game to make the link between the scenarios in the game play and the real-world situations addressed by the game (Garris, Ahlers, and Driskell 2002; Hirose, Sugiura, and Shimomoto 2004; Oo and Lim 2016). From a SDT perspective it is argued that motivational and learning effects are gained if games are designed to allow for player autonomy through sufficient choices and control, competence development through task challenge and completion, and relatedness through engagement with other players (Ryan, Rigby, and Przybylski 2006; Peng et al., 2012). Proulx, Romero, and Arnab (2017) propose a framework that combines game and learning mechanics with different motivational forms (Table 1) and assert that 'the learning outcomes and motivational potential will depend on the implementation of the mechanics within the learning situation where the game is integrated' (91).

Table 1. Motivation potential of game and learning mechanics (Proulx, Romero, and Arnab 2017).

Amotivation	Extrinsic motivation			Intrinsic motivation
Non regulation	External regulation		Integrated regulation	Regulation
Lack of motivation Lowest autonomy		Controlled motivation		Autonomous motivation Highest relative autonomy
No game and learning mechanics aim at amotivation	**Game mechanics**	**Learning mechanics** Accountability	**Game mechanics** Designing ownership Status/titles Strategy/planning	**Learning mechanics** Ownership Planning Responsibility
	Action points Assessment Rewards/penalties Feedback	Assessment Incentive Feedback Shadowing	Collaboration Communal discovery Game turns	Collaboration Hypothesis Reflect/discuss Analyse Experimentation Identity
	Directed progression Time pressure	Demonstration Imitation Simulation	Competition Cooperation Movement Progression Selection/collection Simulate response	Action/task Competition Cooperation
	Appointment Cascading information Questions and Tutorial	Objectivity Questions and answers Tutorial	Role play	Participation
	Behavioural momentum Cut-scenes Story Goods/information Pavlovian interaction Tokens	Guidance Instruction Repetition	Virality	Discover Explore Generalisation

Game operativeness relates to the teaching and classroom context in which the game is played and can include aspects such as time available, costs, area of application, user group, game functionality and clarity of game instruction (Frank 2007; McConville et al. 2017). Time may affect students' motivation if time is restricted for playing the game or breaks introduce unnecessary interruptions. Since developing a tailored game can be costly, often existing games are utilised that can come from different areas of application or are developed for different user groups. If these games are not fully aligned with learning goals and rely on scenarios that strongly abstract or differ from the real-world practice the educational content is covering, students may lose interest in the game play (Garcia et al. 2019). The motivation of students can also be influenced by the extent to which the game is functioning as intended. Programming errors, non-available networks, insufficient game material or limited number of players can lead to frustrations and game drop-outs (Leemkuil et al. 2003). In order to play a game, students require an introduction to the game and its rules. Games often require the processing of large amounts of information, and guidance on how to use the information can prevent students from becoming overwhelmed (Wouters, Van der Spek, and Van Oostendorp 2009). Instructions can be provided through the game itself or (partly) by the lecturer. However, in both cases the clarity of the instructions will account for the ease with which students can start and continue playing a game (Baker, Navarro, and Van Der Hoek 2005).

In sum, previous research has shown that games possess the potential of intrinsically motivating individuals and that in the educational context this potential cannot be expected to naturally play out. Self-determination theory suggests other motivational forms that may become relevant for games used as instructional tools. If motivation of game play is regarded as a cyclic process, it can be expected that the motivation of students to get involved and stay involved in game play will depend on game attractiveness, game learning, and game operativeness. A graphical summary of the relationship between game attractiveness, game learning, game operativeness and game motivation is given with the motivational model in Figure 1. This conceptual model is further explored in the empirical part of our study, since the role of different motivational forms for the involvement of engineering students in educational games and their emergence in the teaching context are still not well understood.

3. Method

A mixed-method case study approach was adopted to get a better understanding of the motivational aspects involved in game playing of engineering students. It can be best described as a partially mixed concurrent equal status design (Leech and Onwuegbuzie 2009). The data collection centred around seven game cases implemented in an engineering course environment in two consecutive years and concurrently combined observations and focus group discussions as well as questionnaire surveys for all games in both years. Qualitative and quantitative data had an equal weight for the study but were only mixed after separate collection and analysis. The qualitative data obtained from observations and focus groups were used to clarify, explicate and enhance the findings from the quantitative data collected through questionnaires (Creswell et al. 2003; Onwuegbuzie and Johnson 2006). The research was conducted by an educational expert and the responsible lecturer of the course.

3.1. Game case studies

Case studies strive for deeper understanding of phenomena in their natural context (Eisenhardt and Graebner 2007) and, thus, are an appropriate strategy for exploring the motivational aspects of educational games in an engineering course environment. The cases comprise seven games that were part of a postgraduate course with a duration of eight weeks and 7.5 study credits (equivalent to 210 h of course work). The course covered the topic 'Infrastructure Management' as part of the

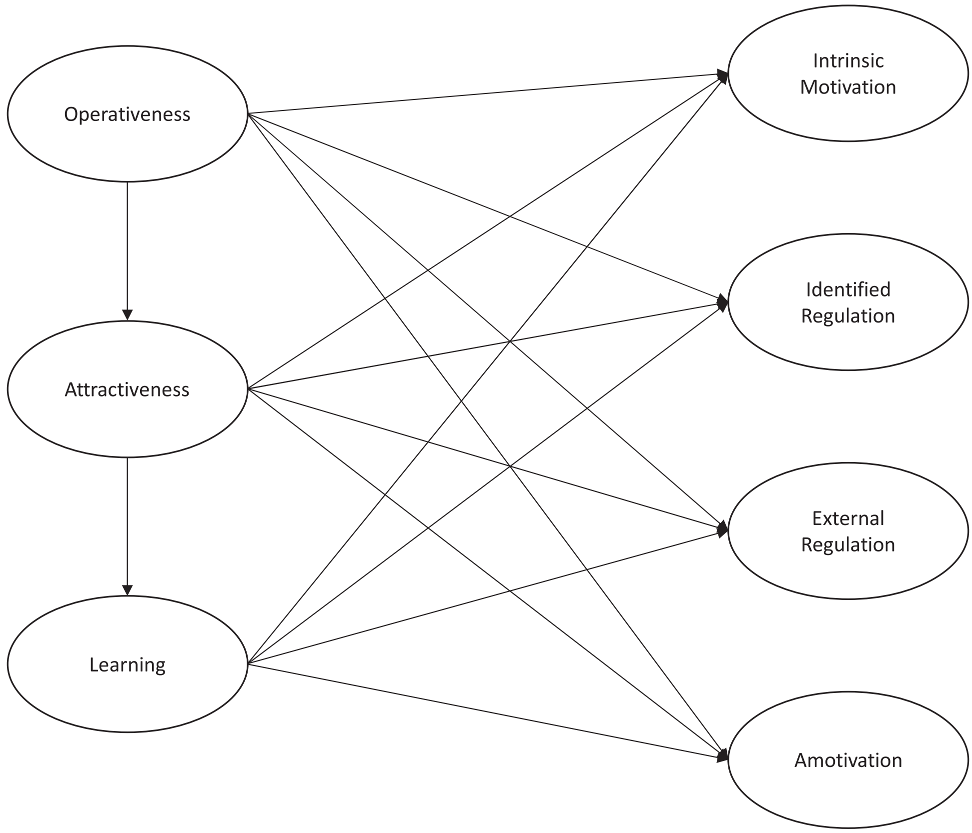

Figure 1. Game motivation model.

Civil Engineering and Management programme, and every week another game was played addressing a different sub-topic. An overview of the games is given in Table 2.

The games were selected, in the first place, according to their contribution to the learning goals of the course. Three of the games were already available (1,6,7), whereas four games were particularly developed to be used as educational tools in infrastructure management (2,3,4,5). Four games are completely computer-based games (1,2,4,7), two games are computer-supported but also use hard-copy instructions (3,5), and one game is a pure board game (6). The time needed to play the games ranges between 45 min (2,4) and 180 min (6).

Five games were applied in the same course in two subsequent years (2,3,4,5,6). One game played in the first year (1) was replaced by another game (7) in the second year. The reason for the replacement was the indirect and loose connection of the game with the course subject, which made it hard for students to learn from the game while playing it. In this sense, five games followed a replication logic with the intention to predict similar results for both years, whereas two games were implemented to contrast the results from the two years (cf. Yin 2013).

The game and learning mechanics of the games and their implementation are presented in Table 3. The main differences between the games are the possibility to play them in a team (3, 5, 6, 7) or as a single player (1, 2, 4), the existence of a strong competitive element (3, 6, 7), the repetitive character (1, 6, 7) or the simulation characteristics (2, 3, 4, 5), and the provision of direct feedback during game play (1, 3, 6, 7) or feedback only at the end of the game (2, 4, 5). Game 6 and 7 combine several game mechanics such as competition, cooperation and behavioural momentum.

Table 2. Game overview.

No	Name/developer	Type	Subject	Learning goal	Duration of playing (min)	Order of playing		No students played	
						2016	2017	2016	2017
1	GasSolution/T-Xchange	Computer-based Single player	Building a gas network to deliver gas in a safe, reliable and sustainable manner	Understanding the complexity and trade-offs of infrastructure management decisions	60	1	–	38	–
2	RiskSwitch/T-Xchange, Author	Computer-based Single player	Increasing the reliability of railway switches	Understanding the consequences of decisions on reliability, cost, maintainability and availability of infrastructure	45	2	4	31	32
3	RAMSes/Viana da Rocha (2012)	Computer-supported Single/ Multiple player	Developing a competitive bridge design for a DBFM tender	Understanding the consequences of design decisions on the costs and risks over the life-cycle of infrastructure assets	60	3	3	20	31
4	HighwayStakes/T-Xchange, Author	Computer-based Single player	Improving the intervention strategy for a highway link	Understanding the consequences of decisions for different stakeholders involved in infrastructure intervention projects	45	4	5	28	28
5	AMImplementation / Wolbers (2012)	Computer-supported Single/ multiple players	Improving a road section by taking strategic, tactical and operational decisions	Understanding the relationship between decisions on strategic, tactical and operational level of an asset management organisation	90	5	2	15	34
6	RoadRoles/Altamirano (2010)	Board game Multiple players	Preparing tenders for the maintenance of a road network	Understanding the relationship between procuring road maintenance and the condition of a road network	180	6	6	17	25
7	BridgeGame/TNO	Computer-based Single/ multiple players	Monitoring and maintaining a bridge to reduce performance risks	Understanding the relationship between infrastructure objectives, infrastructure performance, and infrastructure interventions	60	–	1	–	49

Table 3. Game and learning mechanics.

No	Name	Game mechanics	Learning mechanics	Implementation
1	GasSolution	Tutorial/ cut scene Progression Feedback Behavioural momentum Action points	Instruction/guidance Action/task Feedback Repetition Incentive	• Computer-based introduction of game scenario. • Players need to build a natural gas network, extract the gas from the ground and deliver it to households and companies in a reliable, safe and sustainable way. • 10 game levels with three goals: (i) a certain number of building credits within a specific time, (ii) a minimum score for one or more of the three aspects, and (iii) a maximum score for one or more of the three aspects. • For passing a level, players need to get a certain amount of credits for building the gas network and certain scores for the reliability, safety and sustainability of the gas delivery. The requirements and constraints for delivering gas increase with each level. • Players receive immediate feedback on their actions. They can see on the screen their current building credits and their scoring on reliability, safety and sustainability.
2	RiskSwitch	Tutorial/ cut scene/ story Role play Progression Strategy/planning Feedback Ownership	Instruction/guidance Participation Action/task Planning Feedback Ownership	• Computer-based introduction of game scenario • Players (individuals) take on role as asset manager and need to take 6 decisions that increase the performance of switches of a railway network and need to find an appropriate trade-off between the performance aspects. • To take decisions, they can get advice from a number of experts and stakeholders for the decision-making, and to judge the impact of each decision on different stakeholders. How the next decision situation will unfold is determined by the current decision taken. • Feedback is received with a news article reflecting on the decisions in a journalistic style. Players also receive feedback in terms of their decision style. They also get an overview on the time needed to take a decision, the impacts of the decisions on stakeholders and the experts and stakeholders who gave important advices.
3	RAMSes	Tutorial/ cut scene/ story Role play Competition Collaboration Strategy/planning Feedback Ownership	Instruction/guidance Participation Competition Reflect/discuss Planning Feedback Ownership	• Computer-based and teacher-based introduction of game scenario. • Players (teams) take on role of contractors who need to decide on the design of a movable bridge that has to be competitive for tendering. They are required to develop a bridge design at system and component level that minimises the overall cost including construction costs, maintenance costs and costs related to certain risks. At the same time the design needs to comply with the requirements of the client and needs to meet a target cost level. • The game consists of 4 rounds. After each round the results of overall costs and requirement fulfilment are presented. • After each round players get an overview of the overall costs of their design at this stage and in comparison to the stages before, which cost elements contribute how much to the overall costs, how far the costs are away from the target costs of the client, and to which extent the design fulfils the requirements of the client. They also get an overview of the total costs of the competing teams. • Final feedback is given through plenary discussion.
4	HighwayStakes	Tutorial/ cut scene/ story Role play Progression Strategy/planning	Instruction/guidance Participation Action/task Planning	• Computer-based introduction of game scenario. • Players (individuals) take on role as asset manager and need to take decisions for the development of a new intervention strategy for a highway link consisting of different assets.

(*Continued*)

Table 3. Continued.

No	Name	Game mechanics	Learning mechanics	Implementation
		Feedback Ownership	Feedback Ownership	• To take decisions, they can get advice from a number of experts and stakeholders for the decision-making, and to judge the impact of each decision on different stakeholders. The decision situations depend on each other. How the next decision situation will unfold is determined by the current decision taken. • Feedback is received with a news article reflecting on the decisions in a journalistic style. Players also receive feedback in terms of their decision style. They also get an overview on the time needed to take a decision, the impacts of the decisions on stakeholders and the experts and stakeholders who gave important advices from the players' perspective.
5	AMImplementation	Tutorial/ cut scene/ story Role play Collaboration Strategy/planning Feedback Ownership	Instruction/guidance Participation Reflect/discuss Planning Feedback Ownership	• Explanation about the decision context and selected information are handed out on paper. The decisions are made on separate Excel spreadsheets. • Players (teams) take on the role of public administration and need to take decisions on strategic, tactical and operational level to improve a section of a road infrastructure network. • The game is played in 4 rounds. In each round decisions are made by a different team but based on the decisions another team made in the round before. • There are two feedback moments in the game. The first one is in round 4 when the player/team who made the strategic decisions evaluates the consistency of the decisions made on the three levels. The second one is the calculation of indexes for the strategic/tactical consistency and the tactical/operational consistency at the end of the game and whether the budget spent for improvement measures is in line with the policy topics. • Final feedback is given through plenary discussion.
6	RoadRoles	Tutorial/ cut scene/ story Role play Competition Collaboration Strategy/planning Feedback Ownership Rewards/penalties Behavioural momentum	Instruction/guidance Participation Competition Reflect/discuss Planning Feedback Ownership Incentive Repetition	• The game is explained by the teacher/instructor. • Players (teams) take on the role of contractors who need to prepare and win tenders for the maintenance of a road network consisting of 5 road sections. • The road administration (one player/team) sends out an invitation to tender for the maintenance of the road network for a period of 4 years. The contractors (several players/teams) have to present an offer and compete for the contract and the one that wins it has to maintain the road network in order to make money. The game is played in several rounds. Each round represents a new tender for the maintenance of the road network. • The contractor teams will get feedback after each tender round in terms of the competiveness of their offer. The winning team also receives feedback on the effectiveness of their maintenance planning. The road administration gets feedback on the tender procedure after each round. • Final feedback is given through plenary discussion
7	BridgeGame	Tutorial/ cut scene/ story Role play Progression Competition Collaboration Strategy/planning Feedback Ownership	Instruction/guidance Participation Action/task Competition Reflect/discuss Planning Feedback Ownership	• Computer-based introduction of game scenario. • Players (teams) take on the role of public administration and need to take decisions for monitoring and maintenance interventions to be applied to a bridge in order to reduce performance risks and keep the bridge safe and available within the available budget. • The outcomes of the 5 rounds are immediately visible to the player. At the end of the game an overall score is calculated and the player will be shown on the start page of the game if the score is among the three best scores achieved. • The player receives immediate feedback on his/her decision after each round in terms of the amount of risk reduction and impact on safety, availability and budget. At the end of the game the overall scoring is presented and the player can compare his/her scoring with the highest scoring achieved for the bridge.

In the first year, 40 students and in the second year 56 students were enrolled in the course. The number of students participating in the games differed and ranged between 15 and 49. In total, the seven games were played by 257 students.

3.2. Data collection and analysis

Three different methods of qualitative and quantitative data collection were used to investigate the motivational aspects of the seven games: classroom observations (qualitative) during game play, focus group sessions (qualitative) and surveys (quantitative and qualitative) after game play. All three methods were used for all games in both years in a concurrent manner.

During the lectures when students were playing one of the games, a classroom observation was conducted with the aim of collecting data on students' understanding of and interaction with the game. A standard observation form was used evaluating aspects of game operativeness (user friendliness, clarity of the game, time needed to finish the game, technical performance) and game attractiveness (enthusiasm, engagement, interaction and cooperation between students). Occasionally students were asked questions while playing the game about these aspects. The observations were done by the educational expert who shared and discussed her view with the view of the lecturer after each game play.

After each lecture, a group of five students stayed for a short focus group discussion (20–25 min) to receive immediate feedback from students on the game. The five students volunteered for the focus groups and took part in the discussions of all 6 games. While the observations provided insights into students' direct interaction and engagement with the game, the focus groups revealed the students' experiences of interacting and engaging with the game and their perception of the learning involved. A standardised protocol was used starting with an open question about the strengths and weaknesses of the game. Then more specific questions were raised about aspects of game operativeness (user friendliness, clarity of the game, technical performance), game attractiveness (challenge, engagement, game appearance) and game learning (connection with the course subject, contribution to learning). Also remarkable points from the observation were addressed. At the end of each focus group discussion students were asked to give a suggestion for improvement of the game and rank the games from the most to least favourite one. The ranking was used to identify the relative importance of game aspects. During the last focus group discussion, questions were addressed about the added value of the games to the course, the effect on the learning process and recommendations for next year. Again, the focus group discussions were held by the educational expert, and the results were discussed between lecturer and educational expert after each game to reveal differences in interpretation of students' game playing.

At the end of each lecture, all participating students were asked to fill in an online questionnaire with two subsequent reminders sent before the next lecture. The first part of the questionnaire consisted of the 16-item version of the self-report situational motivational scale (SIMS) developed by Guay, Vallerand, and Blanchard (2000), measuring a student's motivation during the game based on four motivational types: intrinsic motivation, identified regulation, external regulation and amotivation. Each type is measured as reflective construct based on the 16 items using a 7-point Likert scale (from 1 = correspond not at all to 7 = correspond exactly). Based on the scores for the four motivational types, a single motivation score, the so-called self-determination index (SDI) is calculated by multiplying the scores of the sub-scales with a weighting factor (+2 for intrinsic motivation, +1 for identified regulation, −1 for external regulation, −2 for a motivation) and adding up the products (Philippe and Vallerand 2008). The SDI score can range between +72 and −72 with a lower value indicating a lower self-determined motivation.

The second part consisted of several statements measuring game attractiveness, game learning and game operativeness as formative constructs. Game attractiveness was measured with three indicators: challenge ('The game was sufficiently challenging for me'), engagement ('I felt engaged while playing this game') and appearance ('The game looked attractive to me'). For measuring game learning, two indicators were used: understanding ('The game helped me to understand the subject matter') and connection ('There was a clear connection between the game and the learning goals of the course'). Game operativeness was measured with three indicators: time ('I was able to play the game within the timeframe given by the lecturer'), functioning ('The game functioned well'), and clarity ('It was clear to me what I had to do while playing this game'). For each indicator a 5-point Likert measurement scale was used (from 1 = strongly disagree to 5 = strongly agree). Open-ended questions were added to give students the opportunity to comment about strong and weak points of each game and give suggestions for improvement.

The described measurements for game motivation, game attractiveness, game learning and game operativeness were used to estimate the relationships of our game motivation model (Figure 1). For this purpose Partial Least Squares – Structural Equation Modelling (PLS-SEM) was selected as a variance-based method. PLS-SEM allows the exploratory assessment of non-direct causal relationships between variables relaxing some of the assumptions and requirements of covariance-based techniques such as sample size, formative measurements, and normality (Hair et al., 2013). However, for achieving an acceptable level of statistical power, a minimum sample size is recommended. Since the common '10-times rule' raised doubts on the accuracy of model estimations in the past (Peng and Lai, 2012), Kock and Hadaya (2018) propose the inverse square root method. According to this method, a minimum sample size of 123 is required for our study to achieve a statistical power of 80% or higher. With 198 respondents, our study meets this requirement. The collected data were analysed with SmartPLS 3.0 (Ringle et al., 2015).

4. Findings

4.1. Game motivation

The responses of the students on the situation motivation scale and the SDI scores (median and interquartile range) for each game in each year are reported in Table 4. A positive SDI score indicates that the game was able to stimulate more self-determined forms of motivation, while a negative score indicates that students' motivation was less self-determined when playing the game. The scores indicate that in all games self-determined and non-self-determined forms of motivation were present. Put differently, in all games SDI scores of students range between positive and negative values. For some games these scores even lie within a considerable range (between 72 and −50 for Game 4). Moreover, games do not significantly differ in terms of self-determined and non-self-determined motivational forms. Only Game 7 appears to be more motivating than other games, but even in this game some students felt externally regulated or not motivated at all. Overall, the median SDI scores are positive, which suggests the prevalence of intrinsic motivation and identified regulation. The only exception is Game 2 with a SDI score of −1 in the second year. Another finding is that the type of game does not seem to account for the emergence of one motivational form over another one. The games with the highest SDI scores are a computer-based game (Game 7) and a board game (Game 6) and a computer-based games (Game 2) and a computer-supported game (Game 3) receive the lowest SDI scores. For all games there is no statistically significant difference between SDI and SIMS scores of both years (based on the Mann–Whitney U test at a significance level of $p < 0.05$).

4.2. Game operativeness, attractiveness and learning

The co-existence of self-determined and non-self-determined forms of motivation can be explained by main aspects of game operativeness, game attractiveness and game learning. These aspects were identified through observations and focus groups (Table 5). For game operativeness we could determine clarity of game structure and goals (Game 1, 3, 5, 6), time for playing (Game 3, 5, 6, 7), number of players (Game 2, 3, 4, 7) and functioning of the game (Game 5, 6) to be important aspects. They all

Table 4. Findings for game motivation.

		Game 1 GasSolution		Game 2 RiskSwitch			Game 3 RAMSes			Game 4 Highway Stakes			Game 5 AMImplementation			Game 6 RoadRoles			Game 7 BridgeGame	
		2016	2017	2016	2017	Sum	2016	2017	Sum	2016	2017	Sum	2016	2017	Sum	2016	2017	Sum	2016	2017
Respondents		28	–	24	13	37	13	16	29	16	11	27	10	25	35	11	13	24	–	18
AM Score[a]	MDN	15	–	15	13	14	16	15	15	14.5	13	14	11	12	12	10	13	12	–	8
	IQR	5.75	–	7.25	6.5	6.5	15	4	8	7.25	8	7	6.5	6.5	7	9	3	5.75	–	6.25
ER Score[a]	MDN	17.5	–	17	15	16	18	16	17	17	12	16	16	14	15	18	12	17	–	13
	IQR	6	–	6.75	8	7.5	5	8.75	5.5	3.75	10	7	5.25	6.5	6	7	10.5	9	–	5.5
IR Score[a]	MDN	17	–	17	21	17	18	18.5	18	17.5	20	18	19	20	20	22	18	19	–	20
	IQR	4.75	–	4.25	6.5	5	3	7.25	5	4.5	11	9	6	4.5	4	4	5	5.75	–	4.25
IM Score[a]	MDN	19	–	17	15	17	19	15	17	16.5	17	17	18.5	17	17	23	20	20	–	19.5
	IQR	5	–	5.75	9	7	4.5	4.75	6	9	10	10	5.25	4	5	5	6.5	8.5	–	5.25
SDI Score[b]	MDN	5.5	–	4	−1	4	6	2.5	3	2	16	8	12	13	13	30	19	20	–	28
	IQR	26.75	–	30	36.5	32	32.5	20.25	23.5	39.75	35	35	17.5	26	25	30	27	29	–	18.5

[a]Maximum score = 28/minimum score = 4.
[b]Maximum score = 72/minimum score = −72.

Table 5. Findings for game operativeness, attractiveness and learning.

	Game 1 GasSolution	Game 2 RiskSwitch	Game 3 RAMSes	Game 4 Highway Stakes
Game operativeness	– Instructions were insufficient to start playing – Lack of explanation at higher game levels	– Required careful reading at the beginning – Stimulation of discussions if played in pairs	– Missing clarity of goals at the beginning due to time restrictions – Different pace of teams led to idle time – Limited number of teams resulted in large teams with unequal participation	– Required careful reading at the beginning – Stimulation of discussions if played in pairs
Game attractiveness	– Achieving high scores was perceived as challenging – Direct feedback on scores and level – Competition was triggered between students	– Dilemmas were challenging – Less dynamic due to similar decisions in a row – Less attractive due to missing direct feedback – No competition between students	– Interaction within teams high during game – Working in teams is perceived as attractive – Competition between teams facilitated engagement – Direct feedback on tender price per round	– Dilemmas were challenging – Less dynamic due to similar decisions in a row – Less attractive due to missing direct feedback – No competition between students – Repetition experienced because similar to game 2
Game learning	– Discussion limited to gameplay and progress – Difficulties in abstracting from game content – Missing link between game and course objective	– Contributing to learning due to realistic view on decision-making – Link with course content was difficult to make	– Contribution to learning because of clear link between lecture and game	– Contribution to learning through discussion after game play – Clear link with course content – Knowledge was partly available from other courses

	Game 5 AMImplementation	Game 6 RoadRoles	Game 7 BridgeGame
Game operativeness	– Difficulty to understand goals and structure of the game due to decisions lines simulated – Amount of reading was not supportive for starting game play – Excel macro of game did not work at all computers – Dependency on other team led to idle time	– Lots of information to be processed at the beginning – Many clarifying questions asked and test round needed – Idle time due to change between tender preparation and tender evaluation – Bankruptcy of contractor team led to exclusion from game	– Not much explanation needed to start playing – Time for playing was underestimated, not all teams could finish – Teams of 5 students are perceived as too big for having meaningful discussions
Game attractiveness	– Student were enthusiastic when moving between decision rounds – Interaction within teams during gameplay – Challenge stemmed from thinking about rationale behind decisions of another team – Feedback on decision consistency at the end	– Increased interaction within teams – Engagement through competition between contractor teams – Complexity of tender process challenged students – Direct feedback on tender success per round	– Complexity of trade-off between objective, performance and budget was challenging and stimulated discussion – Competition facilitated engagement – Direct feedback on objective, performance and budget per round
Game learning	– Contribution to learning through link with assignment – Feedback from game is not sufficient for learning	– Contribution to learning through realistic situation and direct experience of decisions in a tender	– Contribution to learning through discussion after game play, – Direct feedback in game is not sufficient for learning – Not much prior knowledge needed to play game

had a rather negative motivational effect. Students disengaged from game play if they had difficulties in understanding the instructions, had insufficient time for finishing rounds or could not contribute due to large teams. The attractiveness of the games emerged from the challenge of the game content (Game 2, 4, 5, 6, 7), engagement through interaction (Game 3, 5, 6), competition between teams (Game 1, 3, 6, 7) and direct feedback on performance (Game 1, 3, 6, 7). We observed that the combination of interaction and competition had a strong motivational effect on students to engage and continue with a game. Direct feedback on team performance intensified this effect. The students' perceived learning from the games is related to the link between game and course (Game 1, 2, 3, 6, 5), discussions after game play (Game 1, 4, 7), a realistic game content (Game 2, 6) and the students' prior knowledge (Game 4, 7). However, a prerequisite for learning was that students perceived the game attractive enough to engage and did not disengage during game play due to operational issues.

It is the combination of game operativeness, attractiveness and learning that accounts for the motivational effect of the games on students. In both years all students participating in the focus group discussions ranked Game 6 as first place. Game attractiveness was mentioned as the main reason for this. The bidding rounds for maintenance work were perceived as challenging and realistic. The students could directly feel and experience the bidding competition in their role as contractors. From the perspective of the students, the strong interaction within and between contractor teams and the direct feedback on team performance after each bidding round added to the attractiveness of the game. However, the game required a very extensive introduction and test round to understand its principles and rules, which diminished its attractiveness and learning and even led to single negative SDI scores for this game. The importance given to aspects of game attractiveness, learning and operativeness by the focus group students then also resulted in a different ranking of the other games in both years.

4.3. Relationship between game motivation and game operativeness, attractiveness and learning

The relationship between game motivation and game operativeness, attractiveness and learning was investigated with the PLS-SEM approach. The evaluation of measurement and structural model followed accepted guidelines for PLS-SEM (Ringle et al., 2012; Hair et al., 2013).

4.3.1. Measurement model

The four motivation forms were treated as reflective constructs, whereas game operativeness, attractiveness and learning were measured as formative constructs. For assessing the measurement of reflective constructs four evaluation criteria are suggested: internal consistency reliability, individual indicator reliability, convergent reliability and discriminant validity. Composite reliability (CR) is used to assess the internal consistency of the constructs (Table 6). All four constructs have CR values of 0.869 or higher, which is above the suggested threshold of 0.7 and thus provide evidence for the constructs' internal consistency reliability. For the individual indicator reliability factor, loadings of 0.7 or higher are regarded as satisfactory. Two indicators have loadings below this threshold and were removed. After removal, the loadings of the other indicators remained at a level above 0.7, which indicates their reliability (Table 6). The average variance factor (AVE) is a measure for the convergent validity and shows values of 0.692 or higher for the four constructs. which is above the suggested threshold of 0.5 (Table 6). For assessing discriminate validity, the Fornell-Larcker criterion is used. which compares the square roots of the AVE values of the constructs with the constructs' correlations. For the four motivation constructs, the square roots of the AVE values are higher than their correlations with the other constructs, which is an indication of their discriminate validity (Table 7).

The measurement assessment of formative constructs is based on two criteria: collinearity and indicator weights (Table 8). For assessing collinearity issues, the variance inflation factor (VIF) is used. All indicators of the three constructs have VIF values below 2.0, and thus collinearity is not an issue. By using bootstrapping based on 5000 random subsamples, the indicator weights were

Table 6. Assessment of reflective measurements (internal consistency reliability, individual indicator reliability, convergent validity).

Reflective construct	AVE	CR	α		Reflective indicator	Loading
					Why are you currently engaged in this activity?	
Intrinsic Motivation	0.726	0.914	0.874	IM 1	Because I think that this activity is interesting	0.833
				IM 2	Because I think that this activity is pleasant.	0.875
				IM 3	Because this activity is fun.	0.879
				IM 4	Because I feel good when doing this activity.	0.820
Identified Regulation	0.734	0.892	0.822	IR 1	Because I am doing it for my own good.	0.808
				IR 2	Because I think this activity is good for me.	0.883
				IR 3*	By personal decision.	0.498
				IR 4	Because I believe this activity is important for me.	0.853
External Regulation	0.692	0.869	0.783	ER 1	Because I am supposed to do it	0.876
				ER 2	Because it is something that I have to do.	0.878
				ER 3	Because I do not have any choice.	0.734
				ER 4*	Because I feel that I have to do it.	0.692
Amotivation	0.732	0.916	0.878	AM 1	There may be good reasons to do this activity, but personally I do not see any.	0.847
				AM 2	I do this activity but I am not sure if it is worth it.	0.897
				AM 3	I do not know; I do not see what the activity brings me.	0.848
				AM 4	I do this activity, but I am not sure it is a good thing to pursue it.	0.828

AVE – Average variance extracted; CR – Composite reliability; α – Cronbach's alpha; *removed from the final measurement model.

Table 7. Assessment of reflective measurements (discriminant validity).

Factor construct		1	2	3	4
Intrinsic motivation	1	0.852*			
Identified regulation	2	0.656	0.857*		
External regulation	3	0.253	0.374	0.832*	
Amotivation	4	0.469	0.654	0.437	0.855*

*Square root of AVE.

Table 8. Assessment of formative measurements.

Formative construct		Formative indicator	Loading	Weight	VIF
Operativeness	CLEA	It was clear to me what I had to do while playing this game.	0.393	0.225*	1.138
	FUNC	The game functioned well.	0.780	0.798**	1.136
	TIME	I was able to play the game within the timeframe given by the lecturer.	−0.465	−0.620*	1.036
Attractiveness	CHAL	The game was sufficiently challenging for me.	0.863	0.470**	1.748
	ENGA	I felt engaged while playing this game.	0.849	0.466**	1.599
	APPE	The game looked attractive to me.	0.812	0.245*	1.953
Learning	CONN	There was a clear connection between the game and the learning goals of the course.	0.791	0.252*	1.774
	UNDS	The game helped me to understand the subject matter.	0.982	0.815**	1.774

**$p < .01$; *$p < .05$; VIF-Variance inflation factor.

obtained and their significance tested. For all constructs the indicator weights are significant. However, their relative and absolute contributions to the constructs differ. For the construct 'Operativeness' the indicators 'Functioning' of the game and 'Time' available for playing the game are relatively important, whereas the indicator 'Clearness' of the game has a low relative importance. The absolute importance of clearness is also low. The negative sign of the indicator 'Time' suggests a reverse coding effect on the construct and its subsequent relationship with motivational forms. Both indicators 'Challenge' and 'Engagement' possess a high relative and absolute importance for the construct 'Attractiveness'. The indicator 'Appearance' only shows a higher absolute importance. The same holds for the indicator 'Connection' of the construct 'Learning'. For the indicator 'Understanding' relative and absolute importance are high.

4.3.2. Structural model

The assessment of the structural model is based on five criteria: collinearity, path coefficients, coefficient of determination, effect size and predictive relevance. The VIF values of the three constructs game attractiveness, operativness and learning are used to test whether collinearity issues are present when predicting each motivation construct. The values range between 1.442 and 2.003, and thus there are no collinearity issues. The central criterion for assessing the structural model is the coefficient of determination R^2 that explains and predicts the variation in the dependent constructs. The R^2 values of intrinsic motivation, identified regulation, amotivation, learning and attractiveness are not very strong but are satisfactory for an explorative study (Table 9). However, game attractiveness, operativeness and learning can only explain 12% of the variance in external regulation. The predictive relevance of the model is supported by the Q^2 values that are above zero and ranges between 0.064 and 0.301. When looking at the effect size, f2 game attractiveness has a medium effect size on intrinsic motivation (0.196), and learning has a medium effect size on identified regulation (0.182) and amotivation (0.157). The effect sizes of operativeness on the motivational forms are small.

The model estimates are shown in Figure 2. The estimation of the path coefficients revealed that the most important predictor for intrinsic motivation is game attractiveness (0.483, $p < 0.01$) (Table 7). Learning (0.141, $p = 0.063$) and game operativeness (0.099, $p = 0.115$) do not play a direct role in intrinsically motivating students. For identified regulation, learning is of higher importance (0.434, $p < 0.01$) than attractiveness (0.178, $p < 0.05$). Operativeness also does not have a direct influence on identified regulation (0.091, $p = 0.214$) The same holds for external regulation (−0.041, $p =$ 0.640). Here, attractiveness is also not of importance (−0.076, $p = 0.472$), whereas learning has an effect (−0.272, $p < 0.01$). The negative sign indicates a reverse relationship. The higher the experienced learning in the game, the lower the externally regulated motivation. This relationship is also present for amotivation with learning as strong predictor (−0.411, $p < 0.01$) compared to operativeness (−0.152, $p < 0.05$) and attractiveness (−0.142, $p = 0.129$).

The model also shows positive relationships between operativeness and attractiveness (0.525, $p < 0.01$) and between attractiveness and learning (0.626, $p < 0.01$) (Table 7). The analysis of total effects then reveals that attractiveness has the strongest effect on intrinsic motivation (0.572, $p < 0.01$), followed by operativeness (0.400, $p < 0.05$). Attractiveness also has the strongest total effect on identified regulation (0.450, $p < 0.01$), but the learning effect is very close to it (0.434, $p < 0.01$), and operativeness effect is only somewhat smaller (0.328, $p < 0.05$). Learning shows the strongest total effect for external regulation (-.272, $p < 0.01$) and amotivation (0.411, $p < 0.01$), closely followed by attractiveness (−0.246, $p < 0.01$; -.399, $p < 0.01$). Again, the total effect of operativeness on external regulation (−0.178, $p < 0.05$) and amotivation (−0.361, $p < 0.05$) is comparatively smaller.

5. Integration and discussion of findings

Educational games are considered instructional tools that put students in a position to take ownership of their learning and that are able to foster experiential learning of students. An often-made assumption underlying the learning effectiveness of educational games is their motivational power (Boyle, Connolly, and Hainey 2011; Bodnar et al. 2016). If appropriately designed, educational games are expected to intrinsically motivate students. Students play a game because they experience it as an enjoyable and worthwhile activity. Since game play and learning are seen as intertwined, learning itself becomes a worthwhile activity (Ozcelik, Cagiltay, and Ozcelik 2013). Our study intends to shed a more differentiated light on the motivational aspects of educational games applied in an engineering course environment and was particularly interested in the motivational forms involved in game play and the circumstances explaining their emergence. It follows recent calls to examine learning and motivational effects of educational games in engineering contexts in more detail (Deshpande and Huang 2011; Bodnar et al. 2016). Its contribution to these calls is

Table 9. Direct effects, total effects and predictive relevance.

	Intrinsic motivation		Identified regulation		External regulation		Amotivation		Attractiveness		Learning	
	Direct effects	Total effects	Direct effects	Total effects	Direct effects	Total effects	Direct effects	Total effects	Direct effects	Total effects	Direct effects	Total effects
Operativeness	0.099 ns	0.400*	0.091 ns	0.328*	−0.040 ns	−0.178*	−0.152*	−0.361*	0.525**	0.525**	–	0.329*
Attractiveness	0.483**	0.572**	0.178*	0.450**	−0.076 ns	−0.246**	−0.142 ns	−0.399**	–	–	0.626**	0.626**
Learning	0.141 ns	0.141 ns	0.434**	0.434**	−0.272**	−0.272**	−0.411**	−0.411**	–	–	–	–
Predictive relevance	$R^2 = 0.409$ $Q^2 = 0.270$		$R^2 = 0.369$ $Q^2 = 0.245$		$R^2 = 0.118$ $Q^2 = 0.068$		$R^2 = 0.350$ $Q^2 = 0.237$		$R^2 = 0.276$ $Q^2 = 0.189$		$R^2 = 0.391$ $Q^2 = 0.301$	

$^{**}p < .01$; $^{*}p < .05$; ns – not significant.

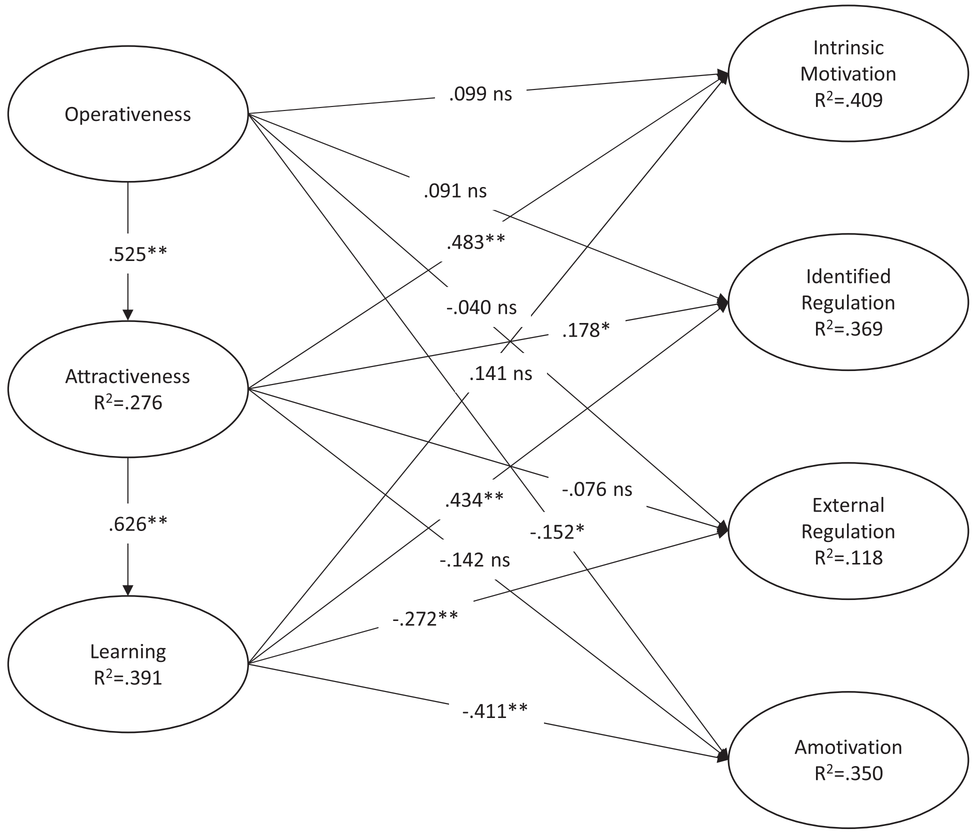

Figure 2. Results of game motivation model estimation $^{**}p < .01$; $^{*}p < .05$; ns – not significant.

twofold: First, it shows that different motivational forms can co-exists in game play and, second, that their emergence results from the combined effect of game attractiveness, game learning and game operativeness.

5.1. Co-existence of motivational forms

The results of our study obtained from seven case games put the overconfidence in the motivational power and, thus, the learning effectiveness of games in engineering education more into perspective. They revealed that different motivational forms can co-exist when students play educational games. In all games, self-determined motivational forms (intrinsic motivation and identified regulation) and non-self-determined motivational forms (external regulation and amotivation) could be identified for both years. For all games positive and negative SDI scores of students are determined. Overall, these findings support previous research from other educational domains already indicating that the use of games does not automatically lead to intrinsically motivated students in an educational context (Gunter, Kenny, and Vick 2006). Although we did not compare games with other instructional tools, the consistency in the co-existence of different motivational forms in the seven games suggests that also in engineering, educational games are not necessarily more motivating than other instructional tools. Our results also show that the type of game (computer vs board game) does not matter. The affinity of a younger generation with computer games may support the application of games in education but does not guarantee the motivational appeal of these games for students. However, with a range between 3 (Game 3) and 28 (Game 7) of the median SDI scores, the seven games show differences in their overall motivational effect. One possible explanation for the difference are the game mechanics. The games with higher SDI scores (Game 6, 7) incorporate more game mechanics conducive to self-determined motivational forms than other games. The type of game mechanics seems to be less relevant since the same mechanics can be also found in the other games, but not all of them combined. We argue that it is more important to combine game mechanics addressing all three intrinsic human needs (autonomy, competence, relatedness) to increase the motivation potential of games. For our two games 6 and 7, this could be achieved with ownership and role play (autonomy), competition and collaboration (relatedness), and progression and strategy/planning (competence). Yet, the co-existence of different motivational forms shows that putting attention to game mechanics alone will not ensure motivated students.

5.2. Games and their teaching context

Since games are tools used in an educational context, their motivational effects will depend on the circumstances under which they are applied (Proulx, Romero, and Arnab 2017). Our study suggests that the emergence of different motivational forms in games results from the combined effect of game attractiveness, game learning and game operativeness. Based on our results, game attractiveness has a significant direct effect on intrinsic motivation, whereas the direct effect of game learning and operativeness on intrinsic motivation is small and insignificant. These findings support previous research that sees game characteristics as the primary drivers for students' motivation (Garris, Ahlers, and Driskell 2002; Gee 2005). Our results furthermore suggest that particularly challenge and engagement play an important role for the attractiveness of the games for students. Since there is a strong link between game attractiveness and game mechanics, these findings support our previous argument to combine game mechanics such as strategy/planning and collaboration to make games challenging and engaging and thus attractive to students.

However, game attractiveness alone cannot explain the existence of other motivational forms. Its direct effect on identified regulation is small and for external regulation and amotivation even insignificant. Put differently, focusing on game attractiveness can increase self-determined motivation of students but cannot prevent non-self-determined motivation. Our case results show that particularly game learning can explain the emergence of different forms of extrinsic motivation. It has a significant direct effect on identified regulation, external regulation and amotivation. This suggests that students participating in the games expected to learn something from the games (Iten and Petko 2016). The game play became a valuable activity for them. and if they did not experience sufficient learning during game play, they rather stopped playing. This behaviour could be observed for Game 2 and 4 that did not provide any direct feedback within the games on decisions made by the students. An implication is the incorporation of direct feedback as game mechanic or plenary in-between feedback that enable students to extract and express the learning directly from the game (Proulx, Romero, and Arnab 2017; Wouters and van Oostendorp 2017).

Our analysis also revealed that game attractiveness itself can indirectly influence non-self-determined motivation through the learning from a game. The cases indicate that if game tasks are perceived as too difficult or too easy to perform because they do not match students' current level of knowledge, students will experience less learning from the game. As a consequence, they become less motivated to continue playing and will regard game play only as an activity demanded from them to do. Considering different levels of difficulties within a game but also other instructional methods preceding games can address the knowledge variance of student populations. This could be observed for Game 3 where students were able to directly connect the game to the knowledge provided in a lecture given before the game play. Our results suggest that an attractive game is a prerequisite for learning becoming a personally valued outcome of game play. Attractive games engage and challenge students who are better able to memorise relevant information and sort out irrelevant information and, thus, are able to learn from the game (Kim et al. 2017). At the same time, attractive games entail the risk of undermining intended learning goals. In our study this became evident for Game 1. Although the game provided a challenging and engaging experience for students, it was difficult for students to link the content of the game to the goals of the course and identify the principles of infrastructure management while playing the game. As a consequence, the game resulted in a low median SDI score and was replaced by Game 7 as introduction to the course. Game 7 addressed the relevant aspects in infrastructure management more directly which in combination with the attractiveness of the game led to a high median SDI score and significant differences in terms of non-self-determined motivation compared to Game 1. Game 7 was able to remove non-self-determined motivation because students could clearly embed the game in the overall course content, which allowed them to learn from the game. The understanding of the subject addressed by games and the connection of games to the course content are important aspects of the experienced learning from games. Tutorials, introductory sessions and test rounds can help students in understanding the role of a game in a course.

The investigated cases also show that the available time for the game play, the functionality of the game, and the amount and clarity of game instructions can become critical issues for the motivation of students. However, game operativeness does not directly affect students' motivation. Only for amotivation a small significant direct effect is present which can stem from idle times, not working macros and too large teams as observed in Game 3, 5 and 6. The motivational importance of game operativeness then lies in its indirect effect via game attractiveness and learning. It provides the grounds for keeping the attractiveness of games as prerequisite for learning. Functional deficits and restricted time in some games attenuate the attractiveness of the games. Students felt no longer fully engaged due to unintended breaks or interruptions and experienced the game as too challenging since they had difficulties in understanding the instructions or were not able to finish tasks in the game (Leemkuil et al. 2003; Frank 2007). They finally did not perceive to learn from the game. For a teacher this means, first of all, controlling for possible operational game deficiencies to deploy the motivational effects of game attractiveness and learning.

5.3. Limitations

Of course, our study has some limitations which, first of all, become manifest in the weak to moderate prediction power of game attractiveness, game learning and game operativeness. A reason might be found in the restricted relevance of aspects forming the constructs, and future studies could include more aspects. Particularly autonomy or control is an aspect considered relevant for game engagement also in the educational context. Another limitation concerns the learner component. Our study did not account for personal characteristics of the students and their possible effects on students' motivation. For example, the level of current knowledge a student brings to the game play may have an influence on the perceived challenge of the game and learning gained from the game. In this regard, our research focused on postgraduate students enrolled in a civil engineering and management programme, and students with a different background may experience games differently. It would be interesting to see to which extent game learning as an explicit value plays a role for students at different study levels and engineering programmes.

6. Conclusion

In this research we were interested in the motivational forms that are relevant for engineering students to become involved in educational games and the circumstance that can explain these forms. Based on our findings, we can conclude that educational games as any other instructional tool in engineering include the co-existence of several motivational forms and that the interplay of game attractiveness, game learning and game operativeness can explain this co-existence. Game operativeness becomes a basic condition for educational games to unfold their challenge and engagement potential, which in turn will frame the learning experience of students. An implication from our study is that the design of games in engineering education should incorporate multiple game mechanics to address intrinsic human needs and increase the motivation potential of games. Another implication is to not only focus on game mechanics but also see them always in relation to the teaching context in which games are used.

Disclosure statement

No potential conflict of interest was reported by the authors.

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