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The merit of educational games in sustainability education

Dahlin J.-E. [1]

[1]Department of Energy Technology, Royal Institute of Technology (KTH), Sweden.

jonerikd@kth.se

Abstract

The act of integrating sustainable development into higher education places a special set of challenges on teaching methods because of the nature of the subject. The challenge includes addressing such matters as: how to deal with complexity, how to deal with 'messy' problems, how to deal with change processes, and how to deal with stakeholder perspectives and values, to name a few. Previous studies have shown that board games and simulation games are beneficial when training students how to deal with those issues. Games offer a platform for interpersonal interaction and the possibility of experiencing simulated situations that otherwise would be too expensive or difficult to deliver in a safe training environment.

In this work, two educational games are evaluated regarding to which extent they deliver a deeper understanding of specific issues: fact-based knowledge build-up, complexity and systems thinking, and perspectives on values, from a sustainability point of view. The games used in this study are Dilemma and Fishbanks. Three undergraduate student groups at the Royal Institute of Technology in Sweden, comprising 300 students in total, are surveyed.

The study shows that games are a more effective teaching tool than traditional teaching methods. Specifically, students playing games perform better at exams than students that do not play games, and games contribute positively to students' ability to understand issues relating to systems thinking and complexity. Also, playing games increases the number of interactions between students in the classroom and lead to more discussions on the topic between students than does traditional teaching.

Keywords: educational games, board games, simulation games, innovative educational tools, innovative teaching

1 Introduction

Modern technology and the modern economic system is unparalleled from a historical perspective in enabling longer, healthier, richer and safer lives for a majority of the population in the world today than what most humans have experienced in history (WHO, 2015; Pinker, 2011). On the other hand, the carrying capacity of the natural systems have already been passed in many aspects and once human activities have passed certain planetary boundaries there is a risk, due to the laws of system dynamics, for irreversible and abrupt environmental change (Rockström *et al*, 2009).

There is no universally accepted definition of the term "Sustainable Development". Rather, there exists a range of definitions, with variations in details depending on ideological values (Heinberg & Lerch, 2010). Different perspectives on sustainability originate from different opinions, positions, views and stakeholder perspectives. "Sustainable Development" is indeed a subject of ***values***.

Another aspect that makes sustainability a difficult subject to learn is the fact that sustainability issues are often inherently complex. As has been shown by Meadows *et al* (1972), properties of system dynamics, such as conflicting time scales, may lead to the overexploitation of resources and eventual system collapse. Espinosa (2011) argues that this insight is reason to change the way we deal with sustainability issues today into one which takes ***complexity*** into consideration.

One professional group that is especially exposed to sustainability related challenges on a regular basis is engineers. They work in a context were values and complexity have a large impact on decision-making on all levels, with potentially large consequences (Fenner & Cruickshank 2014). Engineering is about finding solutions to technological, social, economic, environmental and other challenges by putting empirical method and science into practical implementation. Arguably, engineers have a significant role in the process of turning the direction of society onto a sustainable path.

The act of integrating sustainable development into higher education places a special set of challenges on teaching methods because of the nature of the subject. Those include addressing such matters as: how to deal with complexity, how to deal with 'messy' problems, how to deal with change processes, and how to deal with stakeholder perspectives and values, to name a few. Many of those challenges can be summarised in two overarching (non-mutually exclusive) categories: issues that has to do with *values* and those that has to do with *complexity*.

Dealing with issues of values and complexity require skills that are difficult to acquire through traditional educational methods. Active learning, such as learning through simulations and games, has been strongly advocated for example by Maier & Keenan (1994) and Smith (1992). Active learning techniques require students to work together in small groups to experience, analyse, criticise and perform problem solving instead of passively listening to a lecturer. It provides practical experience and promotes education via experiential learning techniques in more complex situations.

The use of board games, simulation games and role plays have shown to be beneficial when training engineering students (Darling *et al*, 2008; Dahlin *et al* 2015), e.g. as an effective way of improving teaching efficiency, demonstrating opposing views and encouraging an element of collaboration as well as competition in a non-threatening environment. Games offer a platform for interpersonal interaction and the possibility of experiencing simulated complex situations that otherwise would be too expensive or difficult to deliver in a safe training environment.

However, merely using games per se is not sufficient to achieve any significant learning (Zapalska & Brozik, 2008). It is essential that games address explicit learning objectives and that it has been determined specifically how the games are expected to contribute in meeting those. There must also be a review where the instructor can follow up on those learning objectives, where the students' experiences are transformed into concrete learning, e.g. a debriefing seminar or an appropriate assignment task (Lederman & Fumitoshi, 1995). The format of board games is intrinsically interactive, making them appealing as platforms for interpersonal communication e.g. by demonstrating differences in values and personal position. Dahlin *et al* (2013) showed positive synergistic effects between large group lectures and playing board games, when a discussion based board game was used to stimulate conversations around sustainability issues.

In a study by Dahlin *et al* (2015), a range of seven simulation games, board games and role play games were analysed and shown to contribute positively towards meeting certain key learning objectives in the engineering education for sustainable development curriculum. With those earlier findings as a foundation, two educational games are evaluated in this paper in more depth regarding to which extent they are efficient in delivering a deeper understanding of primarily three specific issues: fact-based knowledge build-up, understanding complexity, and understanding values.

2 Methods

2.1 Teaching environment

This study was performed at the Royal Institute of Technology in Sweden (KTH), within a 1.5 ECTS course module called *Introduction to Sustainable Development for Engineers* (KTH, 2016). Games have been used within this module since the first time it was given in 2012. The module is given at several programmes and intended as a foundation for subsequent courses. The work presented in this paper is performed during delivering the introductory course module in academic year 2015-2016.

The module includes two lectures (à 3 hours), a homework assignment, self-study readings and a knowledge test. Games are used in a seminar series where the following games are played:

Dilemma (Dahlin, 2016): a board game where participants have to know facts about sustainability and debate various dilemmas to be successful. Skills that are developed in this game are general awareness of sustainability, and understanding different perspectives in attitudes and values.

Fishbanks (Meadows et al, 1993): a multiplayer computer-aided simulation game, in which participants play the role of fishing companies seeking to maximise their net worth as they have to deal with variations in fish stocks and catch. Skills that are developed in this game are systems thinking and understanding complexity.

2.2 Participants

Participants in this study belong to three undergraduate engineering student groups:

- ***ML1112:*** 1st year students (n = 102), 3 year programme, *ADS* = 11.80
- ***MJ1103:*** 1st year students (n = 159), 5 year programme, *ADS* = 19.50
- ***MH1025:*** 2nd year students (n = 39), 5 year programme, *ADS* = 18.79

where n designates the number of participants in each group, and *ADS* is the admission score to enter each programme (maximum 20.00). Games were used in groups ML1112 and MJ1103. Group MH1025 was a control group without any game sessions but with a lecture (45 min) on complexity instead, and otherwise identical teaching. All groups received otherwise the same traditional teaching.

2.3 Measures

2.3.1 Survey questionnaire

A questionnaire is given to the students before and after the course module, consisting of several closed-ended and open-ended questions. The closed-ended questions, intended to measure the students' own perception of their understanding and how the topic relates to the engineering profession, are:

Q1. "How good is your understanding of the topic of sustainable development?"
Q2. "How important is the topic of sustainable development for professional engineers?"
Q3. "How important do you think your future employer will think that it is that you have knowledge in sustainable development?"

They are measured on a 5-point scale where 1= poor/not at all important and 5 = good/very important. The open-ended questions are included in the post-module questionnaire and intended to measure the students' opinions on how games contributed to their learning. Those are:

Q4. "List three things that you appreciated by playing Dilemma?"
Q5. "List three things that you appreciated by playing Fishbanks?"
Q6. "What impact did board games have on your learning of sustainable development?"

The survey questionnaire is performed digitally online. It is distributed 1-2 weeks before the course module, and opened again 1-4 weeks after the course module.

2.3.2 Computerised knowledge test

The computerised knowledge test is a multiple choice test with 40 questions randomly selected from a large question bank, being two hours long and set in an exam hall with a certified exam guard present. The passing score is 30/40 in all cases. The objective of the knowledge test is to evaluate whether students had read and understood the content of the course literature.

2.3.3 Homework assignment

For the homework assignment, the students are expected to find a system (natural or anthropogenic) with complexity features and competing time scales. Specifically, the system should demonstrate a tendency for system collapse. In groups ML1112 and MJ1103 this assignment is given in connection with the Fishbanks seminar. In group MH1025 the assignment is given in connection with a traditional lecture providing a theoretical discussion of such a system.

The assignment (maximum 2000 words, one week duration) is performed individually and rated pass/fail. There is also a meta-assessment, performed exclusively for acquiring data for this study, on a 3-point scale where 1 = fair, 2 = good, 3 = excellent.

2.4 Hypothesis

The hypothesis of this paper is that games are a more effective teaching tool for education in sustainable development than traditional teaching. In particular, games are well suited for learning towards the following learning objectives: (i) learning to comprehend different perspectives in attitudes and values concerning sustainability issues; (ii) learning to understand complexity and systems thinking; and (iii) general awareness of sustainability and learning basic facts.

3 Results

3.1 Result of the survey questionnaire

The response frequencies of the pre- and post-module survey questionnaire, for all student groups, are shown in Table 1.Response frequencies are considered fairly high and consistent over all groups.

Table 1: Response frequencies of the pre- and post-module survey questionnaire, in all student groups.

	Response frequency, before or after course module	
Student group	Before	After
ML1112	62%	23%
MJ1103	48%	25%
MH1025	87%	25%

The results from the closed-ended questions *Q1-Q3* are presented in Figures 1-3.

In Figure 1, the students' perception of their own understanding of the subject is presented (*Q1*, section 2.3.1). It is clear that in all three groups, the general perception of understanding sustainability increased from the pre-module to the post-module surveys. The trend is more pronounced in courses ML1112 and MJ1103 (the mean value M increased from M = 3.0 to M = 3.9 and from M = 3.0 to M = 4.0 respectively), than in the control group MH1025 (M increased from M = 3.4 to M = 3.7). This indicates that games were effective.

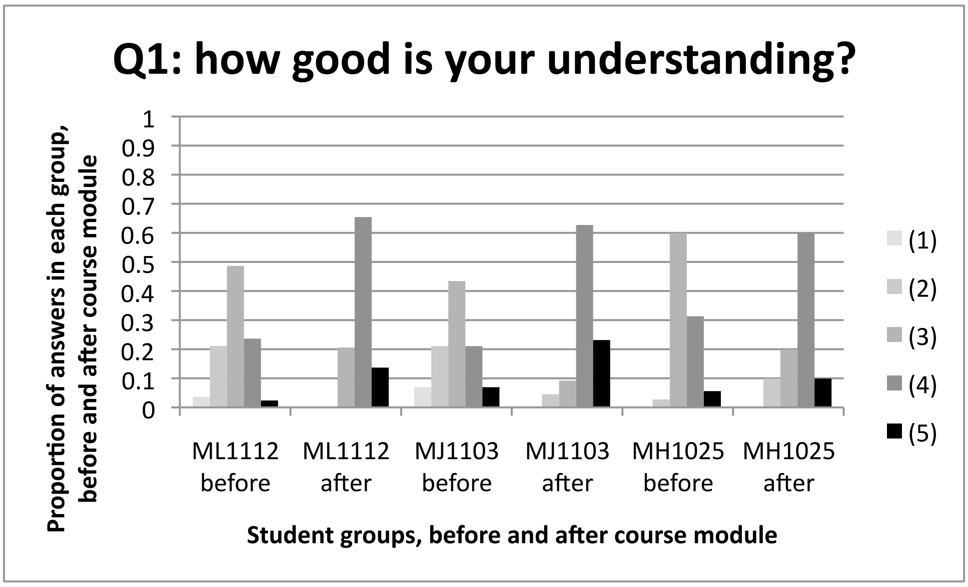

Figure 1: Student perception of their understanding of the topic on a 5-point scale from 1 (poor) to 5 (good).

The students' opinion on how important the topic is for their own future professional career as engineers is shown in Figure 2 (*Q2*, section 2.3.1). Unlike for *Q1*, no clear difference is seen between pre- and post-module in this case, or between courses. Interestingly though, Figure 2 indicates that students believe that sustainability is indeed an important subject for engineers to be knowledgeable in, all mean values being in the range $M = 4.2$ to $M = 4.7$.

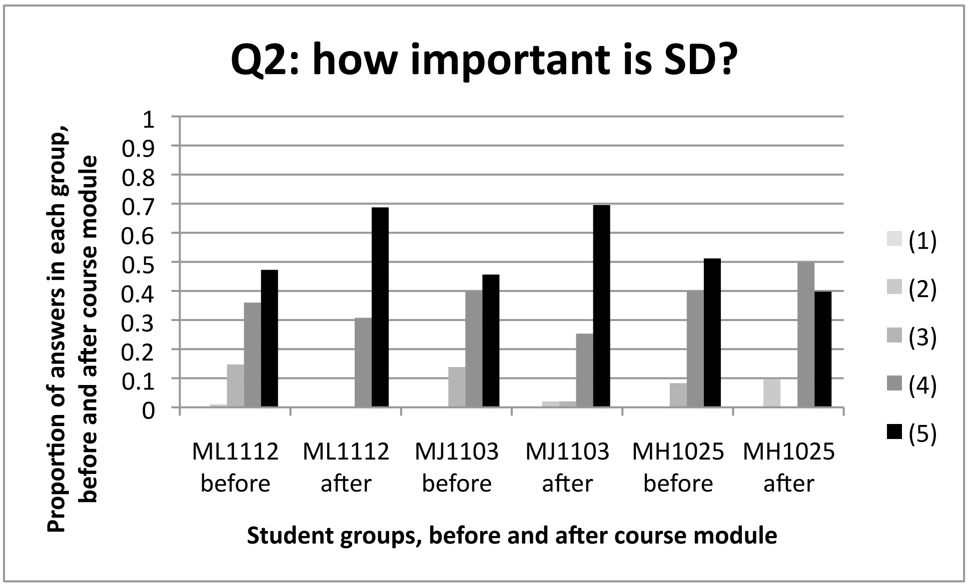

Figure 2: Students' opinion on how important the topic is for their own future professional career as engineers, on a 5-point scale from 1 (not at all) to 5 (very important).

In Figure 3, it is shown how important the students believe their future employer will think that it is that they have knowledge in sustainable development. Mean values range from $M = 3.8$ to $M = 4.2$ with relatively small changes between pre- and post-module answers.

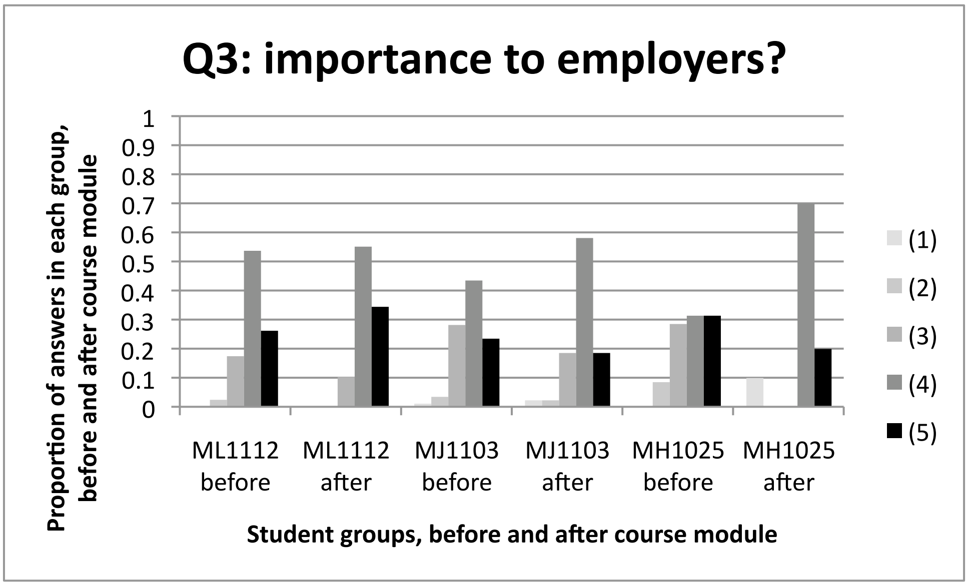

Figure 3: Students' view on how important they believe their future employer will think it is that they are knowledgeable in sustainable development, on a 5-point scale from 1 (not at all) to 5 (very important).

The results from the open-ended questions *Q4-Q6* are not presented in detail here since they consist of circa 200 text strings. A more thorough review of this material will be presented elsewhere, but it is interesting to point out briefly a few results:

Games lead to an increased number of interactions between students in the classroom. Almost all students respond positively regarding the use of games and many of them mention specifically how the games gave them the opportunity to interact with others. Quotes like this are common: "Your ability to debate and having an opinion increases thanks to the many interactions with other students".

Playing games lead to more discussions on the topic between students than traditional teaching. Many of the students explicitly mention the value they got from debating.

3.2 Result of the computerised knowledge test

The result of the computerised knowledge test indicate that the use of games improve the students' knowledge build-up. In Table 2 the test results are presented for all three student groups, as the mean result (on a scale from 0-40) and the fraction of students with a pass score (at least 30 points).

Table 2: Test result (mean value) and fraction of students with a pass score.

Student group	Mean result	Fraction of students with a pass score (at least 30/40)
ML1112	30.7	70.6 %
MJ1103	34.3	92.5 %
MH1025	28.4	33.3 %

The most likely explanation for the difference between the groups ML1112 and MJ1103 (Table 2) is the difference in student composition, seen in the admission score (*ADS*) to enter each programme. As seen in section 2.2, the *ADS* is considerably lower for group ML1112 than for group MJ1103.

The *ADS* for the control group MH1025 is almost as high as for group MJ1103, and considerably higher than for group ML1112. The difference in test result indicates that the use of games in groups ML1112 and MJ1103 enhanced their performance compared to the control group MH1025.

3.3 Result of the homework assignment

The analysis on homework assignment performance indicates only minor differences between the student groups. The result of the meta-assessment (section 2.3.3) in each group is presented in Table 3.

Table 3: Performance at the homework assignment on complexity (on a 3-point scale).

Student group	Mean result
ML1112	1.72
MJ1103	2.05
MH1025	2.03

The group ML1112 shows the lowest result. This can likely be explained by the difference in *ADS*.

4 Discussion

The results from the survey (3.1) and the knowledge test (3.2) indicate that the control group MH1025 acquired less learning from the module than the other groups in spite of them being a more mature group. This is a result in support of using games for knowledge build-up.

The results from the homework assignment on complexity indicate that games positively influence the students understanding of complexity. The control group performed at almost the same level as group MJ1103 (Table 3). It had been expected that the control group MH1025, being a more mature group, would perform better. This result supports using games for understanding complexity and systems thinking. However, this result is arguably not quite as strong as the previous one as there has been no attempt to normalise the results in Table 3 based on the difference in maturity. An equal score may not be regarded enough for a conclusive statement on this matter and more research would be needed.

5 Conclusions

This study shows that games are a more effective teaching tools than traditional teaching methods, especially in education for sustainable development. Students playing games perform better at the knowledge test than students that do not play games. Playing games also increases the number of interactions between students in the classroom and lead to more discussions on the topic between students than traditional teaching.

In particular, games contribute strongly to students' knowledge build-up as well as to their own perception of understanding the topic. It also seems that games contribute to the students' ability to understand issues relating to systems thinking and complexity, even if this trend needs more research to be confirmed.

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