Pedagogical innovation to captivate students to ethics education in engineering

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Abstract

Purpose – The purpose of the article is to develop an innovative pedagogic tool: an escape room board game to be played in-class, targeting an introduction to an ethics course for engineering students. The design is student-centred and aims to increase students’ appreciation, commitment and motivation to learning ethics, a challenging endeavour for many technological students.

Design/methodology/approach – The methodology included the design, development and in-class application of the mentioned game. After application, perception data from students were collected with pre- and post-action questionnaire, using a quasi-experimental method.

Findings – The results allow to conclude that the developed game persuaded students be in class in an active way. The game mobilizes body and mind to the learning process with many associated advantages to foster students’ motivation, curiosity, interest, commitment and the need for individual reflection after information search.

Research limitations/implications – The main limitation of the game is its applicability to large classes (it has been successfully tested with a maximum of 65 students playing simultaneously in the same room).

Originality/value – The originalities and contributions include the presented game that helped to captivate students to ethics area, a serious problem felt by educators and researchers in this area. This study will be useful to educators of ethics in engineering and will motivate to design tools for a similar pedagogical approach, even more so in areas where students are not especially motivated. The developed tool is available from the authors at no expense.

Keywords Game-based learning, Engineering ethics education, Escape room, Board game, Pedagogical innovations

Paper type Research paper

1. Pedagogical innovations in higher education

Over the past decades, it has been acknowledged there is a need for innovations in higher education (HE) at the pedagogical level. Considering the context of HE, pedagogical innovation can be defined as intentional change that intends to introduce new pedagogical practices with the aim of improving learning, interaction or interactivity in a teaching/learning process (Béchard, 2000). The main characteristics of pedagogical innovation in HE includes having (Major et al., 2020) pedagogical intentionality; reflection/introspection in the process of identifying the need, in the search for a way to solve it during development and application; include inventive creativity in the construction of some new tool or methodology; result in an improvement; also include its application and evaluation and involve pedagogical human relationships.
According to Walder (2017), pedagogical innovations promote student learning and professionalism; change students’ behaviour and attitudes, including soft skills and professional ethics (Walder, 2014); improve teachers’ satisfaction by allowing them to reinvent their pedagogical practices and contribute to the pride of HE institutions. Teachers recognizing the need to create and develop new methodologies and pedagogical tools is a key element for promoting pedagogical innovation in HE. It is the recognition of this need that gives meaning to pedagogical innovation and to the effort that the search, creativity and testing process implies. This recognition stimulates teachers and motivates them to change (Peraya, 2009) and guides them in analysing the results obtained, since pedagogical innovation starts from a need and therefore has concrete objectives that it aims to achieve. Depending on the teacher’s perception of the results obtained, the teacher will decide whether or not to adopt pedagogical innovation in their teaching practice (Guerra and Costa, 2021). To this end, it is important to collect data on students’ perception of pedagogical innovation; but it is also necessary to understand the teacher’s perception of its benefits.

2. The need for pedagogical innovation in engineering ethics education

It is usually acknowledged that engineering is one of the professions with the greatest impact on the life of society and each one individually. It is also one of the areas of knowledge that have played a major role in the evolution of unsustainability and could play an important role in developing either sustainability or unsustainability. Smith et al. (1983) argue that “In our technological society the engineer is one of the most powerful agents for change. Engineers are finding new ways to control our environment, to utilize the forces of nature, to increase our productivity, and to improve the quality of life for all. [. . .] The power they will hold makes engineering an exciting prospect, as well as a sobering responsibility.” (p. 6). The commitment to the pursuit of sustainability is rooted in ethical and responsible commitment and action (Oermann and Weinert, 2016). Becker (2011) claims that the ethical dimension is crucial to sustainability, but is often ignored or misunderstood. Committing to sustainability means ethically seeking public welfare. However, several studies show that engineering students tend to disengage themselves “with public welfare and their moral reasoning decreases throughout their engineering studies” (Martin et al., 2021b).

In view of this, it is necessary to promote ethical responsibility in engineering studies. To this end, a more comprehensive engineering education that includes ethical dimension is also necessary. Ethics encompasses the dimension of individual action (micro-ethics) and the public welfare dimension (macro-ethics). These two dimensions are necessary for engineering professionals (Pierrakos et al., 2019).

It is challenging to promote personal ethical commitment and responsibility that is expected of engineering graduates (Martin et al., 2021b). As in the past the skills recognized as necessary for engineering graduates were considerably different, now it is necessary to promote a change in curricula plans and pedagogical methods. Some researchers believe that it is urgent to include ethical education (Monteiro et al., 2019); promote joy and pleasure in engineering studying and promote pedagogic relationships centred in trust and responsibility and engagement with the society (Goldberg and Somerville, 2019).

In Portugal, it seems students perceive engineering courses as difficult (Henriques, 2022), and several statements indicate a disagreement to traditional ways of teaching engineering (Costa et al., 2022). According to some testimonies, this has led to high rates of dropping out, course transfer or experiences of suffering and disappointment (Costa et al., 2022).

A survey carried out in 2022 (Henriques, 2022) showed that in one of the largest Portuguese engineering education institution, 60% of students were at psychosocial risk. The study carried out by Santos (2011) also shows that engineering students display higher mental health risk behaviour. Psychosocial risk is defined as the condition resulting from
interactions, management, organization and the environment where activity is carried out that potentially can cause physical or mental health problems (Leka et al., 2011). Psychosocial risks increase, for example, with aggravated stress in the workplace and are related in particular to dissatisfaction with the activity they develop; with high workload and effort and with excess responsibility (Leka et al., 2011). These problems are not exclusive to Portuguese education and also affect other countries (Kokou-Kpolou et al., 2021; Zhao et al., 2022; Sart et al., 2016; Hambisa et al., 2020).

For Goldberg and Somerville (2019), it is essential to transform engineering education to promote students’ joy and commitment to their own academic path, increasing students’ curiosity, involvement, success and well-being. These could help students better overcome difficulties. In view of this context, it is necessary to develop pedagogical innovation to improve engineering teaching and to promote students’ liking for learning and their professional ethical responsibility. The present study focuses on the teaching of ethics in engineering.

The teaching of ethics in engineering has been a recommended practice since the 90s in Japan, and it has been progressively extended to other countries (Finelli et al., 2012). Nonetheless, it is still a factor that is absent in some countries, and which is considered very difficult to apply in practice (Barendregt et al., 2020). According to Martin et al. (2021b), “engineering instructors highlight the lack of guidance and training on how to teach ethics”. These authors identified several pedagogical methods for teaching ethics in engineering: lectures, presentations, roleplaying, debates, discussions, games, science fiction films or videos, volunteering, study visits and case studies. The most used method is case studies although there is little evidence on the effectiveness of each method either on student learning or on their commitment and involvement (Martin et al., 2021a, b). Young et al. (2021) state that the use of case studies is usually only based on cases in the field of micro-ethics and that the answer is often obvious since they are simplified cases compared to reality. Other authors also point out that the effectiveness of using case studies or other methodologies still needs to be researched into (Bombaerts et al., 2021).

Even when ethics education is included in engineering courses, it tends to be overlooked by teachers and students (Lönngren, 2021). So, one of the biggest challenges is the lack of students’ commitment and interest, as “[s]tudents tend to show disinterest, resistance, and difficulties when exposed to ethics and societal considerations […] as well as a lack of emotional engagement with the course content” (Martin et al., 2021b). The fact that there is a tendency to overlook this training component can impact students’ learning and also enthusiasm and commitment from teachers. This warrants the need for pedagogical innovation in the teaching of ethics in engineering. The pedagogical tool presented in this study is part of the effort to promote students’ interest in ethics education and their engagement. In Portugal, ethics education is absent from most electrical engineering courses (Monteiro and Sousa, 2022).

The present study was born out of the dissatisfaction of a professor of an ethics curricular unit in an electrical engineering course (in Portugal) with the students’ devaluation of ethics education. Subsequently, the teacher considered the necessity to incorporate pedagogical innovation in the ethics curricular unit to help solve these issues. Although the present study has been applied in Portugal to one electrical engineering course, these problems also affect other countries (Lönngren, 2021). Therefore, the study can also be of interest to other countries and other engineering courses.

3. Use of games in engineering ethics education
For Lloyd and van de Poel (2008), games are more relevant to ethical education if they involve a practical dimension (know-how), if they are collaborative and if there is a follow-up debate on the topics and the behaviours covered during the game.
In recent decades, various games have been developed for use in teaching ethics, namely

1. The *Engineering Ethics Challenge* (Carpenter, 2005): a board game in which each group defines an ethical question, its possible solutions and the right one, followed by debate.

2. *Delta Design Ethical Scenario*: to teach ethical design (Lloyd and van de Poel, 2008).

3. BLOCKS (Lau et al., 2013): board game in which students have to build a sentence subject to restrictions that make construction difficult.


5. Reed (2022) researched into the use of three different games:
   - *Cards Against Engineering Ethics* – a card game in which players choose the entity that were responsible for a given event and answer a questionnaire about the choices made.
   - *Toxic Workplaces* – a case study game in which the player reads a case and then chooses one of the pre-set decisions.
   - *Mars: An Ethical Expedition* – an adventure game. Players are informed about a hypothetical case and have to choose between pre-set options that influence the story. The game lasts one semester.

Al Zahrani and Fawzy (2020) are developing a digital game for teaching ethics (based on case studies) in engineering courses. Nel and Carroll (2017) used a role-playing digital game built on academic realistic case studies to evaluate ethical action of players, assessing the decisions taken during the game.

Despite the use of educational games to enhance students’ intrinsic motivation and an active positioning, “the use of games and simulations in educational contexts, although perennially popular with students, has not in general been taken up by faculty, possibly because of the frivolous association that game-playing suggests” (Lloyd and van de Poel, 2008). The present study also contributes to facilitating the use of games in teaching ethics.

4. Objectives and methodology

The context being set, we considered it a priority to have a positive impact on students’ right from the start of the ethics curricular unit, before any content teaching. The aim being to make students aware of the importance of ethics in engineering and how this knowledge can be practical and of use to their future professional life. It was also deemed necessary to contribute to the promoting the joy and to break with the traditional way of teaching as well as surprising students in order to be receptive to new ways of looking at reality, a key element within ethical analysis. Thus, the question at the origin of this research was as follows: what pedagogical innovation can help to increase students’ appreciation and commitment to learning ethics in engineering? Faced with this issue, the objective was to create and test an innovative pedagogical tool with the following objectives:

1. to make students aware of the importance of ethics in engineering and motivate them to their active and committed learning and

2. to raise awareness of how ethics can have a practical dimension in the professional practice of engineering.

Regarding point 2, it was considered it should include an introduction to the Professional Deontological Codes (PDC) that regulate the engineering profession in Portugal and to
contemporary ethical currents in a captivating way, since these are contents that students previously referred to as theoretical and uninteresting (Lønngren, 2021) and are directly related to professional practice. Taking into account the established objectives, the tool should be applied at the beginning of the curricular unit of Ethics and Deontology Applied to Engineering (EDAE) to make students curious and aware of the topic and so establishing the foundations to develop the ethics education.

The methodology used included the steps summarized in Figure 1. The assessment of the developed tool was conducted through the collection of data related to the students’ perception (using a questionnaire before and another one after the implementation of the action) and the perception (written records) of the professor. The pre-action questionnaire and the post-action questionnaire were carried out, using a quasi-experimental method, which is a methodology considered adequate to evaluate the effectiveness of pedagogical tools (Gatti et al., 2019). The questionnaires consisted of questions whose answer was a five-point Likert scale, semi-open questions and open questions. The results of the pre- and post-action questionnaires were treated from both a qualitative and quantitative perspective in their interpretation and analysis. The records made by the professor (one of the co-authors of this study) were analysed qualitatively. Student attendance was also recorded.

A convenience sample was used, consisting of 73 students of the curricular unit of EDAE (second year) of a Portuguese electrical engineering course. The students (9.5% are female) were divided into two groups: one have after work/evening classes (11%) and the other study in the day time (89%). In total, 41.9% of the students are between 20 and 23 years old; 24.3% are over 25 years old; 17.6% are under 20 years old and 16.2% are between 23 and 25 years old. Of students, 15% never studied philosophy during their school career, which constitutes an additional difficulty for teaching ethics. The post-action questionnaire was answered by 64 students. The difference in the number of responses was due to an institutional bureaucratic change in the course’s curricular plan during the implementation of the action, which resulted in a change of some students to other curricular units.

5. Brief description of the developed pedagogical board game
A bibliographical research on the need for pedagogical innovation in HE allowed identifying some fundamental characteristics that this tool should have, as presented in Table 1. Given the identified characteristics, the game-based learning (Marasco et al., 2017) was chosen
because it allows to foster students’ interest, motivation and commitment (Zhao et al., 2022); to learn through practical application to authentic contexts; to awaken students’ curiosity; to transform the learning process into a fun and joyful experience and to promote interaction between students (Barab et al., 2005). It also allows the use of narratives, which play an important role in moral development (Bers, 2001). Among the various game types, it was decided to design, develop and apply an educational escape room board game in the classroom. The choice was based on the fact that it can match the above-mentioned characteristics (arouses curiosity; promotes action with physical, emotional and cognitive engagement; promotes the need for committed, active individual and group search and promotes reflection and data interconnection; as well as the analysis of a complex (albeit fictitious) reality (Bowyer, 2021)). All these skills are highly valued in engineering graduates (soft skills) (Geraedts, 2022). An educational escape room game is an immersive team-based learning and a problem-based learning (Veldkamp et al., 2020). The design of the developed game allowed interconnecting the intended characteristics with the pedagogical objectives, as shown in Table 1. The game was designed and developed by a professor of engineering ethics following the cycle: design, pilot, evaluate and redesign (Eukel and Morrell, 2021).

<table>
<thead>
<tr>
<th>Intended characteristics</th>
<th>Game feature</th>
<th>Pedagogical objectives</th>
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<tbody>
<tr>
<td>Engage the mind and body in the learning process (Bowman et al., 2022)</td>
<td>It implies movement and the search for clues; handling documents on physical support</td>
<td>Contact with documents; PDC; content on ethics in engineering and on contemporary ethical currents</td>
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<td>Engage emotions (fundamental to motivation, attribution of meaning, personal and ethical commitment and appreciation) (Connelly and Joseph-Salisbury, 2019) (Ferreira, 2013)</td>
<td>It focuses on a mystery to unravel, and the narrative included aspects linked to their course, which promoted identification with the context, as well as personal and emotional involvement</td>
<td>Assign meaning to experience and learning and foster moral development</td>
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<tr>
<td>Engage students with close to reality complex situations (Connelly and Joseph-Salisbury, 2019)</td>
<td>The narrative included complex fictional situations partly based on reality</td>
<td>Recognize ethical dimension of professional practice and the practical dimension of ethics; apply ethical analysis to practical cases and promote resilience in complex contexts. Collection, analysis, interpretation and evaluation of information; deduction of hypotheses; synthesis and construction of a reasoned explanation and build ethical reasoning</td>
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<tr>
<td>Be a personal and active discovery (Garrett, 2017)</td>
<td>Implies an active effort of search, discovery, analysis, interpretation, judging, associating and deducing that is done by the students</td>
<td>Express opinion and substantiate their perspective</td>
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<td>Focus on pedagogical relationships between the different actors, which promotes effective learning (Gravett et al., 2021) Promoting a different view of reality (Christensen et al., 2010) Promoting curiosity and motivation Promoting appreciation, joy and a taste for the area (Goldberg and Somerville, 2019)</td>
<td>Is a cooperative group game, involving interaction and debate</td>
<td>Compare, debate, evaluate and judge various perspectives and possibilities Get involved and commit</td>
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<td></td>
<td>Is necessary: to debate the different ideas and reach consensus and openness to the unexpected The mystery to unravel arouses curiosity Play and the mystery to solve are captivating; interaction between students foster good mood</td>
<td>Develop a taste for the learning process and promote personal openness to learning</td>
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Table 1. Systematization of the coherence between the desirable characteristics, the pedagogical objectives and the characteristics of the game

Source(s): Authors’ own creation/work
The game was played in the classroom (in 2 classes of 1 h and 30 min each) in teams (4–6 elements). The game is based on solving a mystery (disappearance of an engineer). The mystery will have to be solved within a time limit of 3 h to allow the reading (albeit partial) of the PDC and other documents and taking into account the complexity of the evidence under analysis. During the game, students have to discover clues and answer questions, obtaining rewards that help guide the evolution of the game and maintain motivation throughout as well as competition between groups. This allowed extra attempts to hit the safe code that contains a central clue. The numbers that make up the code are inscribed disguised on the documents.

At the end of the game, the groups give their reasoned opinion on what they think happened, who is to blame and why. The game involves five characters that are electrical engineers, since the game was applied to electrical engineering students (but this could be adapted to other areas). This allows students to better identify with the game. There is a narrative that frames the game and the characters that justifies the need for the investigation and the role of the players. The clues point to the fact that some characters violated the PDC that regulate the engineering profession, having behaved unethically.

The game allows students to realize that a professional in the field of engineering (in this case, electrical engineering) can choose to act ethically or not and to recognize and value the ethical dimension of professionals. Therefore, in the game there are characters who acted ethically and others who did not (students have to find out which ones).

To uncover the mystery, students have to analyse clues, which include the analysis of the PDC that regulates the engineers in Portugal. This allows the students to know PDC. As the game is played in a group, students can discuss each of the points of the PDC that they find relevant to the case, as well as whether the characters’ behaviours were ethical or not (enhancing ethical analysis, reflection, ethical reasoning and argumentation and ethical discernment – all important components in ethics education). The study of PDC is recognized as one of the components of engineering ethics education (Pierrakos et al., 2019).

The clues also include documents summarizing contemporary ethical currents (e.g. utilitarianism, virtue ethics and deontological ethics) and documents on ethics in engineering. Thus, during the game, the students are able to discuss whether the behaviour of each character fits one of these ethical currents. Contemporary ethical currents are considered important in engineering ethics education (Pierrakos et al., 2019).

The game does not allow to deepen these topics, but it allows for an introduction to the themes and, mainly, the awakening and motivation for the themes, which is one of the main problems recognized in engineering ethics education (Martin et al., 2021b).

Concerning the gameplay, each group analyses the documents of an area of the office belonging to the character that “disappeared”. The documents contain comments that constitute clues of the reasons for his disappearance. All groups review documents from all areas of the office and can go back to reviewing areas where they have already been. The route taken by each group is chosen by the group itself.

The game’s narrative (mystery) only serves to justify (and make it more interesting and appealing) the students’ contact with the documents that contain content on ethics and to motivate their analysis. It also serves to unify the structure of the game and arouse curiosity. The game focuses on micro-ethics, and from this, the macro-ethics and the role of engineering in (un)sustainability will be addressed later on.

6. Results related to the perception of students and professor

(1) To evaluate sub-objective A, the responses (Table 2) to the post-game questionnaire (64 responses), observation and recording of the professor were considered.
From the point of view of students’ perception, 96.9% of the 64 students considered that using the game was beneficial when compared to traditional classes. 90.5% of the students considered that they were more interesting, more active or more motivating. Overall, 59.4% consider that motivation is high or increases with the game.

From the professor’s point of view, it should be noted that in daytime classes:

- Students did not know what an escape room game is, which made it difficult to start the game. Initially, the students were surprised: they stopped to see what was
going to happen, until one student got up and went to look for the clues. From that moment on, the others got up too and started to play in a committed and very active way.

- At the end of the first class, the students did not really want to leave the room. One student commented that “Even if I wasn’t enrolled in this curricular unit, I would attend these classes to find out who the culprit is!” Another student commented in her group “This class is really cool!”. The enthusiasm and joy of most students was very evident: they left the room discussing the mystery and the clues. For the teacher, it was “new and surprising to see the students leaving the room so enthusiastically debating the themes of the class”.

- Upon arriving at the room for the second class, the teacher was surprised by the fact that most of the students were already there debating the game, despite the fact that it was early for the class. They were in a hurry to continue the game and were very curious to unravel the mystery.

- One of the problems identified is the noise that students make when talking to each other in an enthusiastic way and when circulating in the room. Another problem was the game time, as the students wanted the game to last beyond the two lessons as they wanted to analyse the clues more carefully and more often.

In evening classes:

- Students also did not know what an escape room game is. They played enthusiastically (especially the groups with younger students), but much less noisily and slower. Students read the documents much more carefully and therefore took longer to analyse each zone. Older students had more difficulty to understanding the logic of this type of game.

Student attendance recorded by the teacher was high: 25% of students attended 100% of all classes; 80% of students participated in more than 85% of classes; 93.3% of the students participated in more than 70% of the classes and only 5% of the students participated in less than 50% of the classes – these data refer only to daytime students and were affected by the fact that some students only had knowledge that they would be students of this curricular unit in the middle of the academic semester.

(2) To evaluate sub-objective B, we considered

- the answers to pre-game questions (73 answers) about the perception of knowledge that students recognized about PDC and
- responses to post-game questions (64 responses) whether the game allowed them to learn something about PDC and about contemporary ethical currents.

Before the game:

- 17.6% of students said they had no idea what a PDC was; 27% answered they did not know what it was; 37.8% did not take a position; 16.2% answered they knew what it was and 1.4% considered they knew very well;
- As for the knowledge of the PDC, 31.1% answered they had never heard about it; 29.7% said they did not know the codes; 35.1% did not take a position; 2.7% answered that they knew and 1.4% answered that they knew the codes very well.
After the game:

- 75% consider they learned a few things about the PDC; 12.5% consider they have learned many things; 7.8% consider the game allowed them to capture everything they know about it; for 3.1% they did not learn anything new about it and 1.6% consider that before the game they already knew everything about PDC.

- 78.1% stated that the game allowed them to learn something new about utilitarianism/virtue ethics/deontology; 7.8% responded that they learned a lot of new things about it; 7.8% said they learned everything they now know; 4.7% considered that they did not learn anything new and 1.6% answered that they already knew everything before.

7. Conclusions

The results allow us to conclude that the tool developed broke with the traditional way of teaching classes and that students recognized this as beneficial. It allowed students to be in class in an active way, mobilizing body and mind in the learning process and fostering students’ motivation, curiosity and interest. This tool provided active and student-centred learning, as it promoted a process of commitment, search and individual reflection as a result of the characteristics of the game itself. Despite this pedagogical methodology implying much more work and commitment on the part of the students, when compared to traditional lectures, the fact that 96.9% of the students answered that they would like to continue with this methodology in the curricular unit is an indicator of their satisfaction with the method. These data can be corroborated by the professor’s record referring to the students’ enthusiasm and joy during the game and student attendance.

The game allowed students to have a first contact with PDC and with some contemporary ethical currents. The game allowed to look at these themes in a practical and curious way, arousing the interest of the students although it was not possible to deepen the themes during the game due to its limited time. Taking into account that almost all students did not know the PDC before this action, this first contact was made in a dynamic and active environment and applied to a concrete situation and likely to be real, allowed students to value these documents in a practical and useful way and less theoretical. The fact that it was a board game that involved movement and debate fostered interaction between students and enhanced their emotional involvement.

Although the pedagogical tool developed and tested had very positive results, it will be necessary to improve some aspects, namely the game time and its degree of difficulty, especially since the students were not familiar with this type of game. This tool was part of the introduction to ethics in engineering, but it is also necessary to develop innovative and efficient pedagogical tools for other pedagogical objectives throughout the ethics education of engineering students.

The main limitation of the game is its applicability to large classes (it has been successfully tested with a maximum of 65 students playing simultaneously in the same room). The contributions of the study are to have innovations in the teaching of ethics in engineering with the use of a board game and in the profile of the game and the topics covered. This could be useful to all those who teach ethics in engineering courses.

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