Journal on Teaching Engineering, 3:1 (2024) 30-49
ISSN 2795-4005
DOI: 10.24840/2183-6493_003.001_1889

Received: 24 October, 2022
Revised: 30 November, 2022
Published: 2 December, 2024

BONDER - a didactic tool for consolidating knowledge on adhesive bonding technology

Ana Q. Barbosa
Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial (INEGI), 4200-465 PORTO, Portugal (aqueiros@inegi.up.pt) ORCID 0000-0002-1661-9989

Ana Duarte
Instituto de Investigação em Arte, Design e Sociedade (i2ADS), Faculdade de Belas Artes da Universidade do Porto, Rua Rodrigues de Freitas 265, 4049-021 PORTO, Portugal (atsilva@fba.up.pt)

Carolina Leite
3Centro de Estudos de Arquitectura e Urbanismo (CEAU) da Faculdade de Arquitectura da Universidade do Porto, Via Panorâmica, S/N, 4150-564 PORTO, Portugal (cleite@arq.up.pt) ORCID 0000-0002-2229-9758

Livia Barts
Eötvös Loránd University Budapest, Institute for Art Theory and Media Studies, Múzeum körút 6-8., 1053 BUDAPEST, Hungary (bartslivi@gmail.com)

Catarina D. S. P. Borges
Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial (INEGI), 4200-465 PORTO, Portugal (cborges@inegi.up.pt) ORCID 0000-0001-7721-7118

Lucas F. M. da Silva
Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 PORTO, Portugal (lucas@fe.up.pt) ORCID 0000-0003-3272-4591

Author Keywords

Adhesive bonding, board game, didactic tool, knowledge consolidation

Type: Research Article

Open Access
Peer Reviewed
CC BY

Abstract

Adhesive bonding is increasingly used in industries like aerospace, automotive, naval, and railroad to meet EU climate and energy goals. This requires lighter, stronger, more durable, and environmentally friendly materials, which adhesive bonding can provide. To address the growing need for skilled professionals, universities and technical courses offer training in adhesive bonding technology. This study aimed to assess the effectiveness of a didactic tool in consolidating knowledge in this field. The tool was designed to dynamically illustrate the principles of adhesive bonding and the potential defects associated with each manufacturing step. Two groups, one of researchers/experts and another of EAB course participants with varying educational backgrounds, evaluated the tool. Participants completed a questionnaire to provide feedback on the tool's impact and usability.

1. Introduction

Analysing the world around us, it can be observed that in the last three decades there have been radical changes in the way the reality is perceived. The economy and technology have advanced at a vertiginous pace, leading to social changes that also influence how knowledge is communicated and perceived. In the 90s of the 20th century, it was common to learn with the access to lectures supported by transparencies or a blackboard, in this static way the knowledge was passed immutable for years. Student/teacher interaction could be quite limited. Interactive teaching could consist only of listening to an expert on a certain topic followed by questions, a discussion session or the presentation of a case study (Treher 2011). At the beginning of the 21st century, the archaic transparencies were replaced by slideware

from *Powerpoint* (Microsoft Corporation) or similar software's, being the predominant technology used with all kind of presentations (from academic to business) (Penciner 2013). This tool allows greater interactivity, such as animated graphs and diagrams, inclusion of videos and audio files, and the information contained in them is easily revised and updated. Despite its extensive use, this tool is far from being consensual about its effectiveness in the transfer of knowledge. Most teachers have followed the technological evolution and embraced this new tool. However, not always in the best way. Many succumbed to the temptation to include as much information as possible in a short period of time, almost as if in an information explosion (Jones 2003). Edward Tufte (Tufte 2003), emphasises that the use of this software "makes us stupid", both on the side of the audience and the speaker. Use of PowerPoint presentations in themselves is presumed to be unlikely to lead to learning retention, skills development, or behaviour change. Since, if the information is not well structured and prepared (on the lecturer's side), only information is presented without reflection on the content (on the audience's side). Nonetheless, this is a somewhat reductionist view, as *Powerpoint* can be a very powerful tool when used correctly. *PowerPoint* is an excellent resource for presentations, assuming that each presentation is considered first from a pedagogical point of view, taking into account the different ways students learn and attempting for the most part to avoid the traps of passive knowledge transmission. The key to the success of this tool is "when it can be used". According to Jones (Jones 2003), 'When' may be a curriculum issue that is discipline dependent or it may be a resource issue in terms of using in computer projection mode. The typical linear structuring of many lectures can be effectively made more flexible by employing hyperlinking options, both inside and outside the PowerPoint presentation, and by using methods to jump to specific slides that are not part of the linear sequence.

Learning is not at all a linear process and there is no correct formula for teaching a particular topic. In common sense, three major myths have developed about the best ways to learn:

- you learn by listening to experts on a particular topic (Manion and Nixon 2012);

- you learn when you get hands-on (Schwichow et al. 2016);

- experience leads to learning (Treher 2011).

It can be said that these three forms of learning can indeed be effective but by themselves, they may not be enough for knowledge consolidation. When listening to an expert talking about a certain topic, the listener is making his/her own interpretation of what he/she is hearing, which may not be exactly the same as what the lecturer wants to convey. Experiential learning alone may not be enough, if there is no proper mentoring of the activity we are learning, we may do the same activity over and over again without good knowledge transfer. It is necessary to give meaning and reflection in order to convert the experience into knowledge/skill. Similarly, hands-on learning should not be proposed as an isolated approach. It is not enough to do, but to understand why it is being done and how to do it. So, according to Treher (Treher 2011), hands-on and heads-on learning works best. Either alone is not sufficient and properly designed board games are an effective way to provide this combination.

Games, and in particular board games, are not something new, since they are the expression of the ludic nature of the human being (Boghian et al. 2019). Humanity has been playing and learning from these activities for millennia. The idea of introducing board games as an educational tool is traced back to the creation of the first board games in 2200 BC. According

to Hinebaugh (Hinebaugh 2009), early board games took many forms and have always been a not only entertainment but also an educational tool in ancient cultures. According to Fitzgerald (Fitzgerald et al. 1997), an educational game can be defined as an instructional method that requires the learner to participate in a competitive activity with present rules. The majority of the population, at some stage of their lives have played an analogue board game, which makes it so cross-generational (Mora et al. 2015). And although they are not a new trend and all the digitization that society has experienced, according to Sousa et al.(Sousa and Bernardo 2019), board game's recent market trend suggests an increasing interest in analogue games. According to Castell (De Castell 2011), games and in particular board games have increasingly become relevant in formative action nowadays, leading to the emergence of the theory of "Ludic Epistemology": it attempts to find ways of encoding knowledge in the form of games and how to shape the process of knowledge acquisition as a game process.

Games designed for professional purposes and not merely for enjoyment are gaining worldwide attention as they allow players to learn new skills and knowledge, stimulate physical activity, or improve socio-emotional skills (Aburahma and Mohamed 2015). There is a growing demand today for pedagogues to engage students in learning and keep them motivated; to do so, it fundamental to understand the importance of games in learning, as well as how to use game-based teaching and learning (Boghian et al. 2019). Treher (Treher 2011) quote that these kind of games can provide hands-on and heads-on skill and knowledge development for people of all ages on all subjects. There are no barriers of technological knowledge, as can happen when presenting a computer game to a user who is not familiar with this type of games. In the last decades there has been an extensive spread of board games as a learning tool, initially focused on teaching children and adolescents learning skills, but their potential for teaching adults was rapidly observed.

Two major types of learning theories can be considered when using board games for educational purposes:

- behavioural theories;
- constructivist theories of learning.

In behavioural theories of learning based games, the basic element of the learning process is a question that the game addresses to the player; the player's response to this question/stimulus is an answer, which can be either right or wrong; correct answers are rewarded with a positive feedback from the game which further stimulates the player's positive emotions; a wrong answer triggers a negative feedback from the game (Boghian et al. 2019; Rugelj et al. 2018; Zalka 2012). Playing games based on the constructivist theories of learning are designed around the active role of the learner and enable higher levels of taxonomic knowledge to be attained; learning is problem-based, so such games are designed as life stories or fictional stories in which the learner plays a role, identifies with what is happening in the game scenario and actively solves problems. The teacher's role is to select suitable games and to provide guidance and feedback on the learner's progress during play and outcomes, if possible; the teacher's role is to select suitable games and to provide guidance and feedback on the learner's progress during play and outcomes; such games help learners to build appropriate mental models (Boghian et al. 2019; Cojocariu et al. 2014).

Well-designed board games not merely create an engaging atmosphere, they also provide a co-operative, non-threatening, entertaining and at the same time challenging environment in which to focus on content, enhance and enforce learning. The mistakes are valuable in

learning and point out what we need to learn. The board itself provides a visual metaphor to assist in linking the information together. It can be said that game elements, group discussions and problem solving with teammates about the content are conduits for learning (Hinebaugh 2009; Treher 2011). For good knowledge retention, subtle redundancies to reinforce learning and retention should be embedded in the game concept. Board games should have good questions, problems to address, and scenarios to consider (within safe environment without real-life consequences) to enable players to brainstorm and implement what they have learnt (Aebersold et al. 2012; Braghirolli et al. 2016; Wilson et al. 2009). One of the advantages of playing in teams is that players learn together, there is a sense of togetherness and no one feels alone or neglected for not knowing an answer. The questions asked in the game help to assess comprehension of the game content and to flag up where reinforcement of learning is required. Games are ideal for incorporating diverse learning styles. For example, for players who learn best with concrete ideas, games transform abstract concepts. In contrast, players who need to start with big picture analysis are supported by the metaphor(s) of the game itself. Beyond demanding critical thinking, team-based board games will help build communication and relationship skills as players work face-to-face to answer questions or solve problems and together they often discover what they thought they didn't know. The empowerment of collaboration then becomes apparent to all and, in organisational contexts, can transform working relationships, which can be extremely advantageous, since in the hyper-individualistic culture of the modern world, team building can be a challenge for pedagogues (Hinebaugh 2009; Ingalls and Dance 2018). The advantages of gamification transcend the mere learning of concepts, since game experience will enhance communication between players, cooperation, conflict management and risk-taking. But also summarise and enhance relevant information in an easy-to-grasp format and decrease the time required to learn, retain and apply new information.

For board game dynamics to work properly there must be a well-balanced ratio of enjoyment to the transfer of knowledge. It is important to keep in mind that the main objective of a game is to generate enjoyment. When a game loses the fun factor it becomes tedious and not enjoyable to play, losing the players' interest (Hinebaugh 2009). This statement is applicable not only to children's games, but also to games in a professional context.

Although the application of board games is a well-accepted strategy, the success of learning according to this technique may not be consensual. It is not known whether the relationship between games and learning is direct or indirect, and if so, what the mediating variables might be (Wilson et al. 2009). In addition, potential difficulties arise with the strategy as some students may find peer competition threatening or anxiety provoking (Henderson 2005).

In this research, a board game was deliberately chosen rather than a digital game, so that face-to-face contact could be encouraged. In this way, the authors believe that there will be greater knowledge sharing and brain-storming between players and game master. It is aimed to evaluate the effect of board games on the performance of students in a particular course regarding adhesive bonding. Adhesive bonding is a technique under expansion in several key industries, such as the automotive, aeronautic, and naval, among others, particularly because they promote lighter structures (E. A. S. Marques 2021). These novel structures lead to less energy consumption and greenhouse gas emissions, meeting the European Union's current climate and energy policy, which has set a goal of improving energy efficiency in the European Union by 20% by 2020. Due to the industrial expansion of the use of this technology, new-trained professionals, from researchers, specialists and engineers to bonders with skills in the application of adhesives to connect two components are required. Currently in Europe, the

majority of training in this technology takes place at universities (bachelor, master and doctorate level) or in European Federation for Welding, Joining And Cutting (EWF) certified courses. The course focused in this work aims to train bonders (European adhesive bonder – EAB), that are able to identify and act on the main steps of adhesive joining, both from a theoretical and practical stand point, to create good quality joints in different productive processes.

2. Objectives

This study focused on understanding how a board game can be used to consolidate knowledge in adhesive bonding technology. For this purpose, it is aimed to develop a board game. It is intended to design a didactic tool so that, in a dynamic way, students could understand the principles of adhesive bonding and correlate the steps in the manufacturing of an adhesive joint with the possible defects that may occur. The aim is also to analyze the implementation and acceptance of this board game, using a survey.

3. Methodology

According to Boghian (Boghian et al. 2019), the basic structure of a didactic game comprises the following steps:

1. theme/subject and content in accordance with the participants/students' age;

2. didactic aim/educational finality;

3. operational objectives/specific finalities;

4. didactic task/instructions/the training element;

5. game rules;

6. game elements;

7. didactic strategy;

8. the stages of the game;

9. game versions (Da Silva et al. 2018; Boghian et al. 2019).

Following these board game design steps, the BONDER design methodology will be described. In addition to the points described, an analysis was also made of the design elements used to develop this game.

3.1. Subject

BONDER was developed to be a board game for adults who are attending the EWF certified European Adhesive Bonder (EAB profile) course, as well as students attending an engineering course where this subject is taught (e.g. mechanical engineering or materials) (European Federation for Welding 2019, 2015; Barbosa et al. 2021a; Barbosa et al. 2021b). To play this board game, players are required to have a basic knowledge of adhesive technology in order to correctly answer the questions and correlate the scenarios that are proposed during the game. This game was developed to be applied in courses taught in Portugal, so it is written in Portuguese, but given its universality it can easily be translated into other languages.

3.2. Didactic purpose

The BONDER design was based on the manufacturing process commonly used for most adhesive joints produced for both laboratory and industrial purposes, as illustrated schematically in Figure 1. The manufacturing process of a bonded joint consists of several sub-

steps joined together to form a coherent procedure. This procedure includes preparing the substrate surface, measuring and mixing the adhesive, applying the adhesive, assembling the joint, hardening the adhesive, and finally any necessary joint finishing activities. In addition to the steps described in figure 1, general knowledge of adhesion technology, health and safety and raw materials storage and inspection are also included in the game. These steps are essential free from defects adhesive joint production practice and are documented in the EWF guidelines (E. A. S. Marques 2021; European Federation for Welding 2019, 2015).

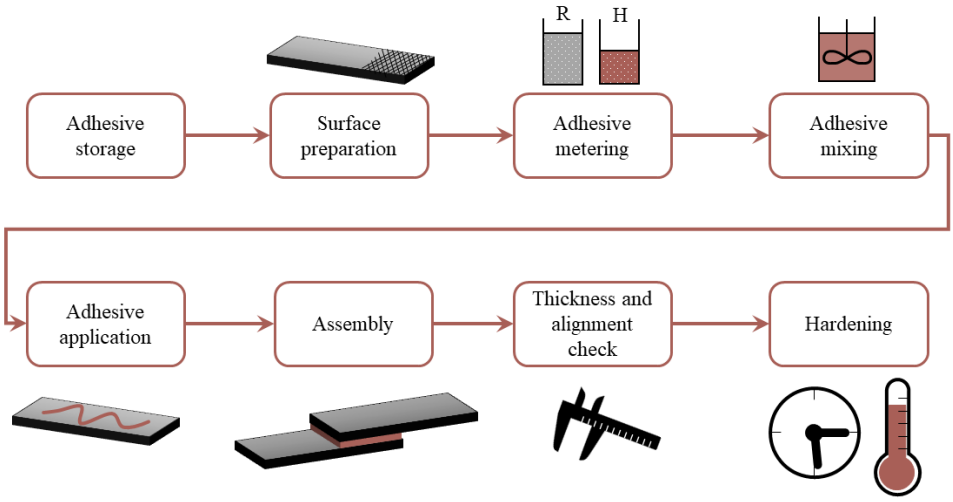

Figure 1 - Procedure of adhesive joint manufacturing (E. A. S. Marques 2021).

3.3. Operational objectives and specific finalities

BONDER, is a board game developed to provide a hands-on and heads-on experience, to assist with knowledge consolidation of classroom contents. It has been designed to meet the needs of an engaging, non-threatening but yet competitive class atmosphere.

3.4. Didactic task, instructions and the training element

Playing BONDER board game involves two main activities: answering multiple choice questions and interpreting hypothetical scenarios. The game consists of a board - divided by steps - game cards - composed of question cards and conditions cards, and game pawns each representing a player or team of players along the board steps. For this reason, each of these eight procedures was made to correspond with the steps on the board game way to victory. Two extra steps being added: a departure point - storage unit; and an arrival - named final inspection.

To advance to the next stage players must correctly answer the questions, and in doing so, they are made to review the theoretical content previously given in class, while correlating hypothetical scenarios that often occur in the production of adhesive joints.

Figure 2, shows the overall layout of the game, where each stage is represented by an icon and different colour to help players identifying each step. The game's different moments are clearly identified: answering questions and interpreting hypothetical scenarios.

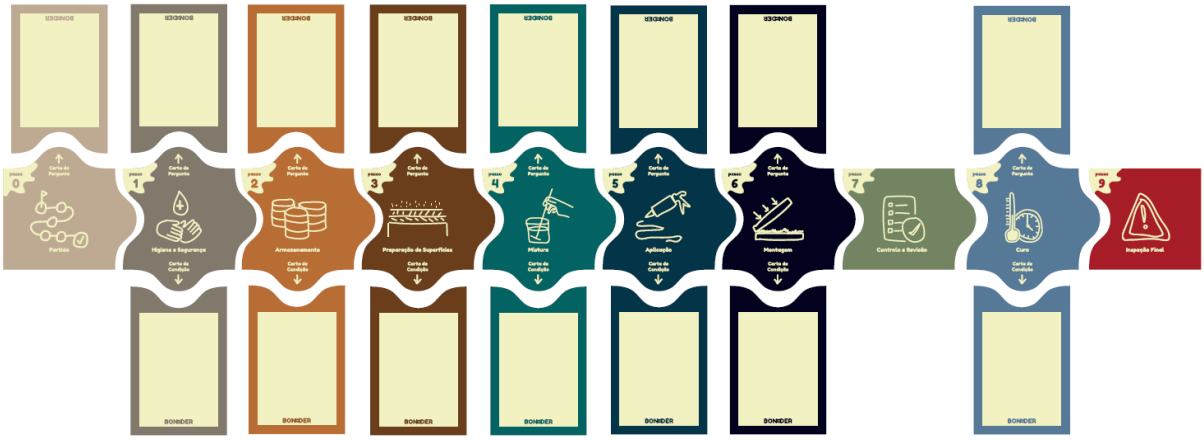

Figure 2 - General layout of the BONDER board game.

As mentioned above, the game is divided into 10 stages, corresponding to different steps in the adhesive joint production process, and to go to the next stage a specific action is required. In some stages, a correct answer to a multiple question is required. In others, players are to receive cards. For example, in stage "0" the players have to answer correctly to a question related to the technology under study. In stages 1-6 and 8, players will not only have to answer a question, but will also receive a card, called a condition card. These cards correspond to possible scenarios that a technician may experience when making adhesive joints. Some scenarios correspond to favourable situations, others to unfavourable ones. Stages 7 and 9 of the game involve these previously given random scenarios as fortunate or unfortunate, as represented in figure 3. In case of having received an unfortunate scenario card, players must not only be able to recognise it as so, but also to correlate the given scenario with its resulting defect. For the scope of the game these defects are: porosities, cracks, voids, unbond, poor cure, and weak adhesion. Selected because they are some of the most often observed in a manufactured joint (see Figure 4), and each given its own card, with its schematic representation, to help with visualisation and memory activation.

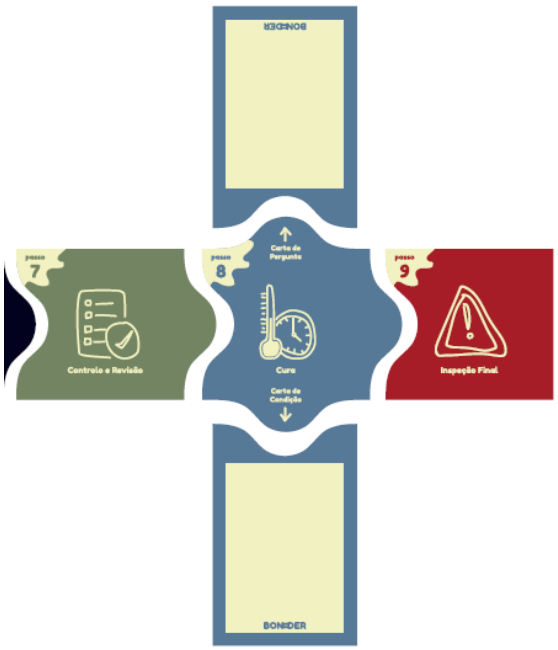

Figure 3 - Section of the game where the control and inspection steps, question cards and condition cards are displayed.

By analysing all the proposed scenarios, the players should understand whether the production process will be successful or which scenarios should be reversed, how and why. In these stages, besides the revision of theoretical knowledge, the player is invited to correlate facts, to consider the effects of an execution error in each of the stages and to have a holistic vision of the whole production process. Due to poor storage conditions, manufacturing issues, internal stresses or even unexpected service conditions, defects may occur in the adhesive joint (adhesive layer or interface). In the manufacturing process, the presence of defects should be detected whenever it is possible, as they can considerably modify the joint strength and lead to premature failure. The defect type, size, and location are three important factors that affect the strength of the joint and must be determined using the quality control methods (E. A. S. Marques 2021).

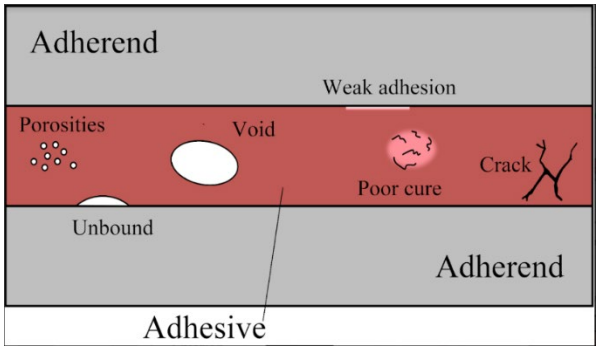

Figure 4 - Defects that can typically be found in the adhesive layer of an adhesive joint(E. A. S. Marques 2021).

This defect diagram served as the basis for the development of one of the stages of the game, the final inspection, schematically illustrated by figure 5. The players in this stage of the game receive a condition card with a certain defect and will have to explain to the Game master and the other players, which defect they are analysing, its origin and how to avoid it and also the consequences of this defect in their working life. With this stage, it is expected that the players will review the multiple knowledge acquired in class and correlate it, by simply observing a defect. A spirit of knowledge sharing should be promoted, where despite the fact that a team only analyses the defect that was allotted to them, they can also learn from the interpretation of the opposing teams. The role of the Game master is also fundamental, as he/she will have the purpose of validating and guiding the sharing of knowledge.

A student can have associated more than one role. Each role is generally assigned to a subset of students. For example, say there are 400 students divided into 14 groups for lab classes. Each of these 14 groups has a number associated, from 1 to 14, and is called class X, where $X \in \{1,...,14\}$. Class 3 is to the set of students of class (group) 3. We proposed *Discord* to 5/14 groups, hence 5 of such roles.

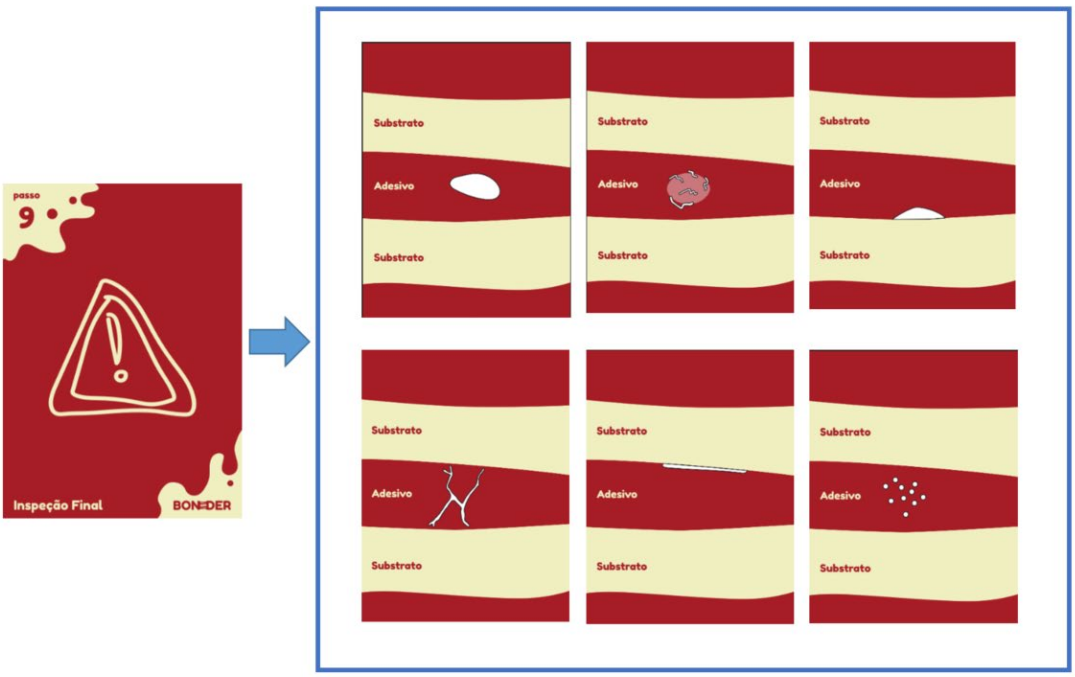

Figure 5 - Final inspection condition charts representing each different defect type, using figure 4 as inspiration.

3.5. Game rules

BONDER is a game designed to facilitate the learning of the adhesive joint process, conceived to be used as a pedagogical tool. This game simulates the ten main steps required to correctly perform an adhesive joint, highlighting the six most common defects that can occur. It is a game divided into rounds, designed to facilitate learning of the adhesive joint process. To win the game, a team must answer all the questions correctly and carry out all the tasks successfully in order to advance through the nine squares of the board and finish the adhesive jointing process. To play the game, an experienced Game Master will be required, preferably a qualified trainer. To prepare the board, the tiles corresponding to the steps should be placed in a row, adding adjacent tiles to be used to place the Question and Condition Cards. Each team starts by choosing a pawn and placing it on the starting square. From "Start" to the “Assembly” step, teams play once per turn, where they have to answer a question related to the step of the stage they are. In case of a wrong answer, the team will have to wait for the next round to try answer a new question. A question card is shown in figure 6. These cards have the same colour code and icons as the step they refer to, for easy identification. On the back of the card there is the question and the different possibilities of choice (three wrong and one correct). The questions will always be asked by the game master.

Figure 6 - Example of the arrangement of a question card.

As teams answer, they should keep the question cards. In the case of a correct answer, the team wins a condition also a condition card, and can proceed to the next round (see figure 7). These condition cards contain situations that could jeopardise the whole bonding process.

Figure 7 -Example of the arrangement of a condition card.

Condition cards must remain face down until the seventh step, Control. The game runs follows until the seventh step (Control).

Once a team reaches the control, it can reveal all the condition cards collected so far, so that in your round you can evaluate if any of them jeopardize the bonding process. If the team cannot indicate all the conditions that could negatively affect the process, they will have to return to the Warehouse house, in order to simulate the details inherent to the real process. Once the teams have all the conditions right, they can move on to the hardening stage. In the hardening round, the teams will again answer a question, also related to this stage. In the event of a wrong answer, they have to wait for the following round to answer a new one. In the case of a wrong answer, they must wait for the next round to answer a new question. In case of a correct answer, the teams In the case of a correct answer, the teams draw a new condition card, which In the case of a correct answer, the teams take out a new condition card, which must also be face down, and If the answer is correct, the teams take out a new condition card, which must also be face down, and proceed to the final revision. The team reaching the "Final inspection" will have to reveal their condition card collected in the previous stage, and as before, assess whether the condition in question jeopardises the joint process.

If they successfully complete this task will be the winner of the game, and will receive an inspection card from the Game Master that will provide information about the defects caused by that condition. However, if they fail to do so they will have to return to the starting house. The first team to complete the final inspection wins, but the game continues until the round is over, giving the possibility to the other teams to complete the inspection in the same round. In the event of a tie, the team with the fewest cards wins answered cards. If both teams have the same number of cards, a final quiz is held to break the tie. Whoever answers wrong first loses.

The box includes:

- 25 board pieces
- 4 pawns
- 64 Question Cards the right answer is marked with > wrong answers marked x
- 56 Condition Cards
- 6 Inspection Cards

3.6. Game rules

The game elements are established in relation to the didactic requirements and tasks of the game. As already mentioned, the game is intended to share as much knowledge as possible, hence the division of players into teams, but it is also intended to foster a healthy and friendly spirit of competition, in order to make the game attractive to play. In the rules there are defined moments in which the players will be penalized for performances that are considered insufficient (incorrect answers or misinterpretation of the scenarios). The positive reinforcement for a good team performance will be defined by the dynamics of the players; no moment of positive reinforcement is contemplated, existing only the winning team and the losers. Although, this game is not intended to encourage competition for its own sake, but to promote cooperation and dialogue between teams. The determination of a winning team will be another stimulus to increase the interest of the game, boosting the players' ego.

However, it is the function of the Game Master, promote a game dynamic that promotes cheering and the feeling of approval and reward for correct answers or good interpretations of the scenarios presented.

3.7. Didactic strategy

As highlighted, this game is to be applied to a very specific target audience, and it is expected that its players already have previous knowledge of the adhesive bond technology. In this context, this game will be seen as a complementary tool for knowledge consolidation. In addition to a review of knowledge and preparation for an exam (traditional form of knowledge evaluation), players will be able to correlate facts and different process conditions. Heads-on and hands-on methodology will be related in the implementation of this game. Common laboratory/industrial situations will be presented and players will be invited to understand their influence on the process.

For the success of this game, the game master should be qualified in the area of adhesive joints. Its role will be much more than a simple " Q&A host". The game master must be able to interpret the conditions, explain in detail each situation presented and, in addition to giving the correct answer, explain why the other options are wrong.

For greater sharing and also to foster an atmosphere of trust, the game is intended to be played in teams (2 or more elements). It is advised that, if possible, the game be played with teams of few elements, since the presence of several teams of few elements instead of a few teams of several elements, leads to slower gameplay, more questions are asked and more scenarios are explored. In other words, with this team formation measure, there will be more knowledge sharing and wider discussions, which is one of the main goals of this game.

3.8. The stages of the game

The stages of the game and their correct order will be of the Game Master's major responsibilities, he/she must ensure that the game follows its established order so that all stages of the game are covered.

3.9. Game versions/complication

The versions of the game (complication) refer either to complicating the game items or to applying the game to different types of students (EAB or engineering students); keeping a record of the versions has formative values for teachers because their construction contributes to the possibility of dealing with concrete situations during the activity. This game is still a prototype and is being tested with different groups with different training needs. Therefore, it is expected that there will be iterations for the improvement of the game.

3.10. Design elements

The BONDER game was designed and developed during the Emergence Science Communication Hackathon. During four days, the team developed the game idea and materialised it by presenting the first physical and ready-to-play version.

The game features the following design elements: logo, typography, colour palette, and illustrations applied to the pieces that compose it. The BONDER logo intends to communicate the game's identity immediately with the introduction of a graphic element that visually refers to the bonding process. The typography intends to be informal and friendly for a game that promotes the assimilation of knowledge in a relaxed environment. The colour palette promotes balance between the different elements and is sequential to assist in the placement and ordering of the pieces on the board. The colour sequence also highlights the continuity and succession of the ten steps involved in the bonding process. For each phase of the game, an illustration was developed to allow immediate identification of the corresponding action.

This game was designed and developed to meet the needs of consolidation of knowledge for courses taught in Portugal. So, all design elements, such as board layout, question cards and conditions, as well as the final inspection cards were written in Portuguese. The images of the game presented in this article are for illustrative purposes only, so their contents are in the native language in which the game was developed.

3.11. Questionnaire to evaluate the implementation of the didactic tool

In order to assess BONDER’s playability, context and its acceptance by the players, an anonymous survey was distributed immediately after the application of this didactic tool. The survey consisted of seventeen questions, divided into three main groups of questions. The first group of questions aimed to understand the game as a didactic tool, i.e. how complex was the game, if they felt they had enough knowledge to play and if it helped to consolidate their knowledge. Six questions are dedicated to this topic in the survey. In a second group of questions, the aim was to evaluate the playability of the game, the total time of the game, the dynamics, and the rules of the game. Seven questions are dedicated to this topic in the survey.

A third group of questions assessed the game design, whether they found the colours and illustrations appealing. Four questions are dedicated to this topic in the survey.

The participants were asked on several questions to rate criteria from 1 to 5, where 1 is strongly disagree (or similar) and 5 is strongly agree (or similar).

4. Results

In order to evaluate the playability of BONDER and its acceptance by players, two test game sessions were conducted. After the game session, the participants were asked to answer a survey. In the following sections the study group will be analysed and their responses to the questionnaire will be evaluated.

4.1. Characterization of the study group

Two groups were used to evaluate BONDER as a didactic tool to consolidate knowledge in adhesive bonding technology. The first group was composed of five researchers in the field of adhesive bonding technology. The second group, composed of eight trainees, participated in an edition of the EAB course and played this game to consolidate knowledge. Analysing the two groups it can be said that both have the knowledge background in the technology, required to be able to play the game. The study population comprised 31% women and 69% men, with an average age of 31 years. The first group was exclusively composed of researchers, representing 39% of the general study population, as shown in figure 8. The second group, with a greater diversity of professional profiles, is composed of manufacturing operators (15%), R&D technicians (23%) and manufacturing engineers (23%).

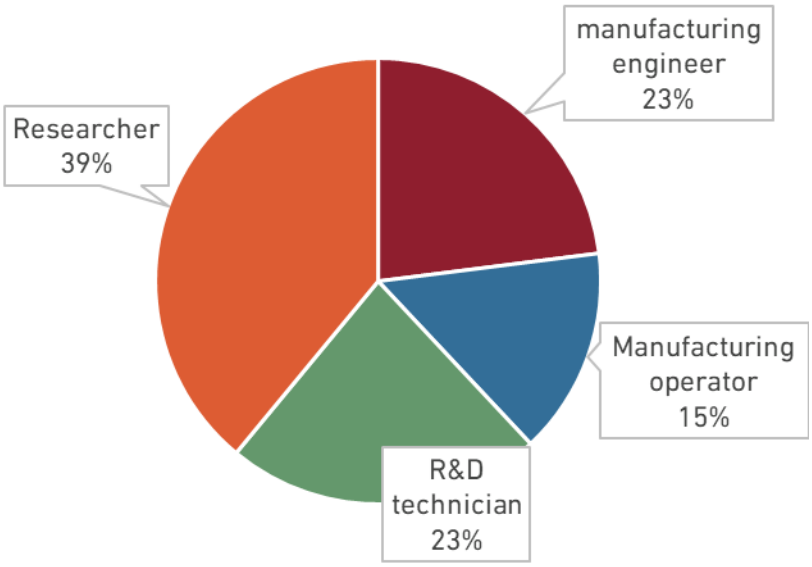

Figure 8 - Professional profile of the population who played the BONDER.

The educational level of the participants was also assessed, and as can be seen from figure 9 there is a wide educational spectrum, from compulsory education to PhD. However, in the game assessment, there is no evidence that this educational spectrum translates into a disparity between the participants. According to their feedback, participants felt in a confident, safe environment, sharing ideas and doubts.

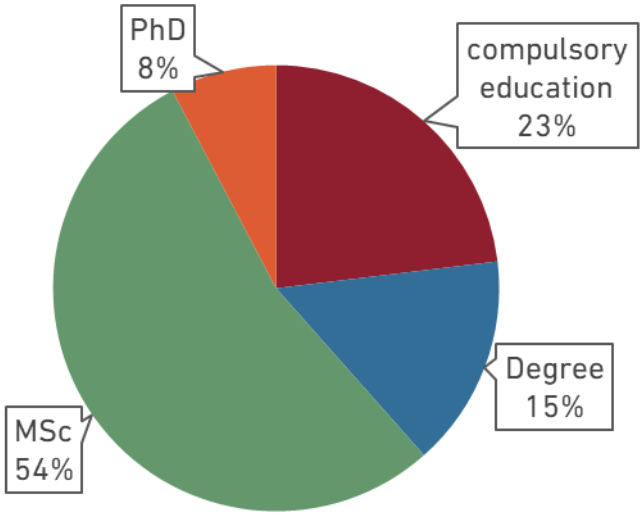

Figure 9 - Educational profile of the population who played the BONDER.

4.2. Survey

The survey was designed to assess three key issues for the evaluation of the game: knowledge consolidation, playability and game design. As stated previously, the participants were asked several questions to rate criteria from 1 to 5, where 1 is strongly disagree (or similar) and 5 is strongly agree (or similar). Consolidation of knowledge was one of the key points of this game, as it is envisaged that this game will be used as a didactic tool instead of the traditional tools, used so far. When players were asked about their confidence playing the game, most felt they had prior knowledge of the technology so were confident playing the game (see figure 10).

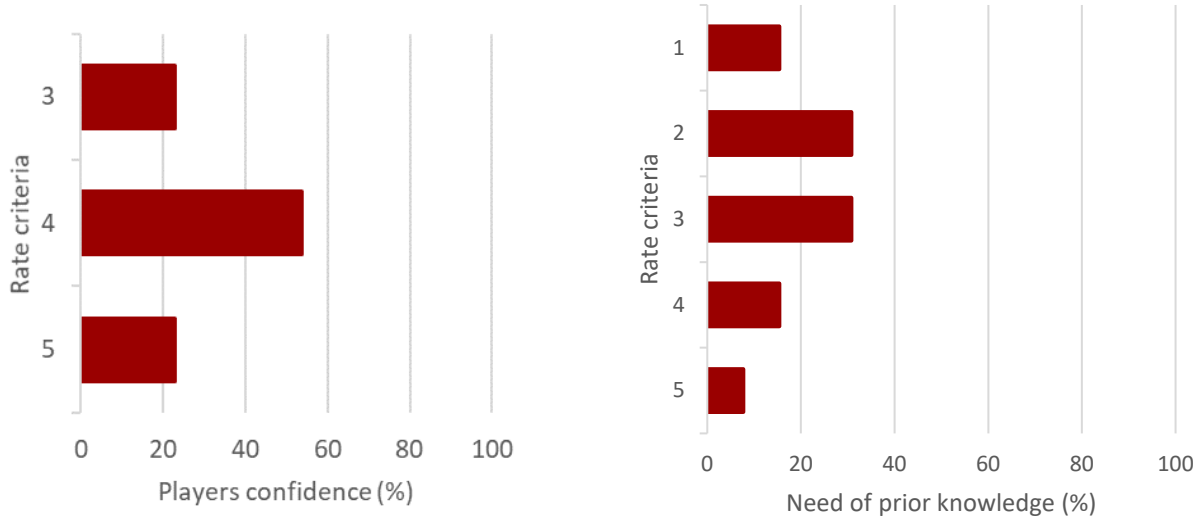

Figure 10 - Results of survey responses: left: players' confidence; right: need for prior knowledge regarding adhesive bond technology.

Regarding the application of this didactic tool to help players on the main stages of production and the defects that can occur in adhesive joints, the answers are equally satisfactory, as can be observed in figure 11. The majority considered it a useful tool in the understanding of these issues, only 1 person considered that this didactic tool was not useful. However, given the

respondent's answers to the other questions of the survey, it is considered that there was a misinterpretation of the question. In order to understand this type of possible mistakes, the survey was constructed in such a way as to foresee and analyze possible misinterpretations of the questions, as there are questions with the same purpose but structured differently.

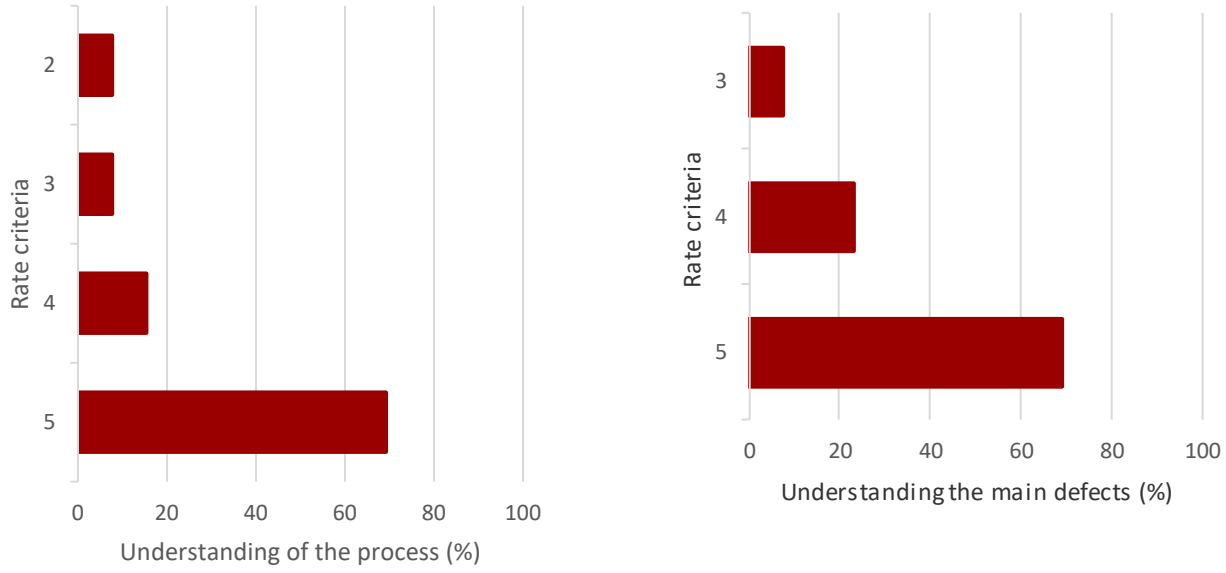

Figure 11 - Results of survey responses: left: understanding the production process; right: understanding the main defects.

When the players were invited to give their opinion on the application of this game as a tool for consolidating knowledge, the acceptance was exceptional, as the majority thought it was an excellent way of learning and considered that with the use of this game they had a better perception of the production of adhesive joints and their defects compared to more traditional methods of explaining contents, as can be seen in figure 12.

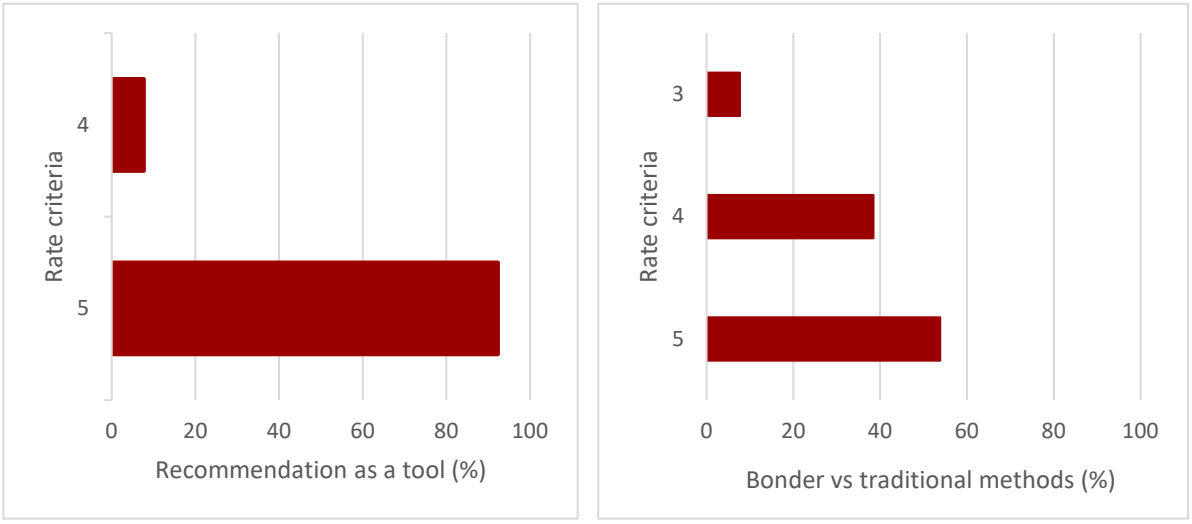

Figure 12 - Results of survey responses: left: recommendation of BONDER as a knowledge consolidation tool; right: better understanding of the adhesive joint production stages and their defects compared to traditional methods.

Afterwards the playability of BONDER was analysed, questions were asked to understand if the rules of the game were clear, if the duration was appropriate and if they had fun playing this game, since that is also the aim of a game, to boost playful enjoyment. The players found

that the rules were clear and well explained both by the booklet included in the game box and by the explanation given by the game master (see figure 13). When asked about their availability and willingness to play this game more often, despite not being a traditional ludic game, the majority considered that it would be interesting to play the game with some regularity, even to review their knowledge (see figure 13).

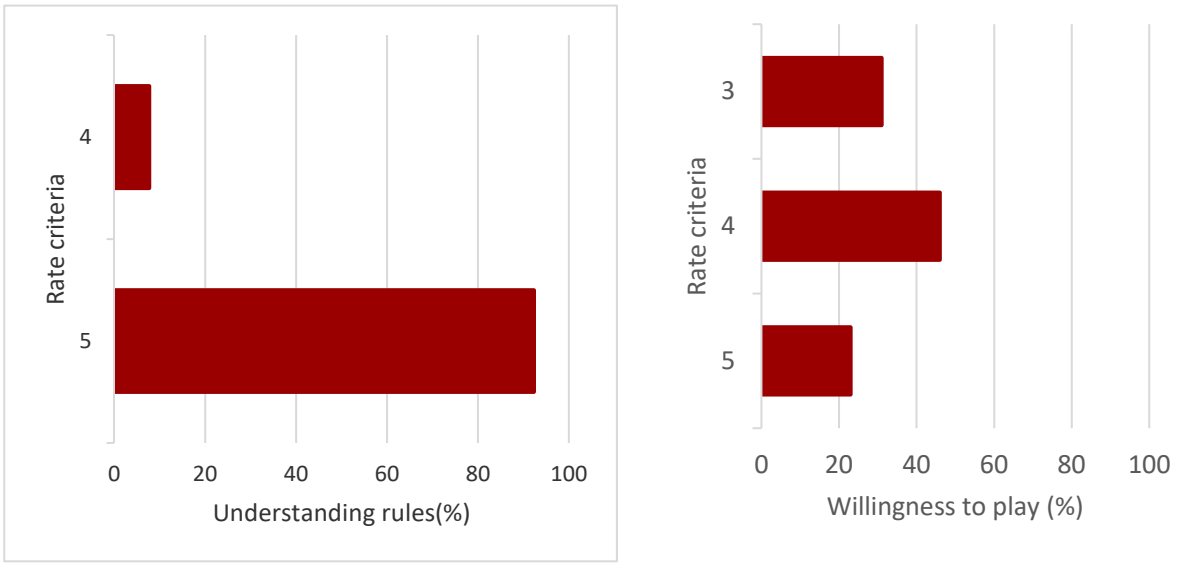

Figure 13 - Results of survey responses: left: understanding of the rules of the game; right: willingness to play BONDER regularly.

When asked about the need for help to play the game, the participants consider that they do not need any help and the game was easy to play, as shown in figure 14. It should be noted that the term "easy to play" refers to playability and not to the difficulty of the questions. The relevance of the game master's role is evident here. The game master should help the players not only in the interpretation of the didactic contents, but also in the dynamics of the game. In addition to the role of arbitrating the game, the game master should be well trained in adhesive joint technologies, so that he/she can help in all aspects of the game. Participants also felt that the time taken to play BONDER was appropriate. The role of the game master is again emphasized here. He/she should regulate the time in order to ensure that each participant has the necessary availability to be able to answer the questions and interpret each scenario. The sharing of opinions should be encouraged and the game master should manage the time wisely, to ensure that the game doesn't get too tedious and that nothing is left unshared. During the two test sessions of this game, it was observed that the existence of more than two teams with few elements was preferable to two teams with multiple players. This allows more knowledge sharing is provided, both by the number of questions asked and the scenarios studied.

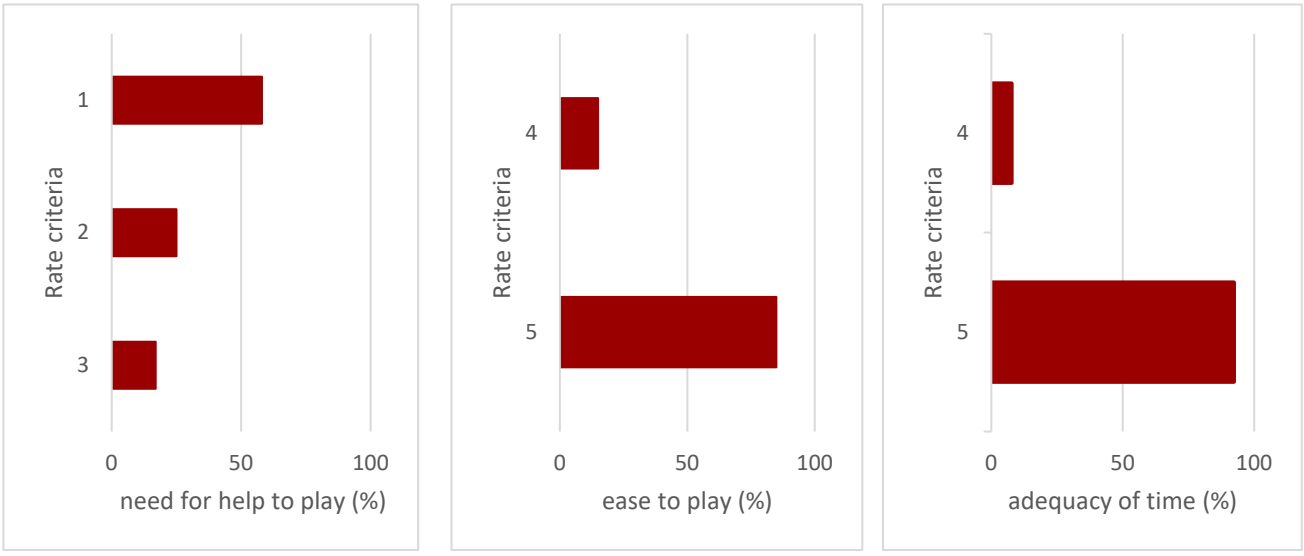

Figure 14 - Results of survey responses: left: need for help to play the game; centre: ease of play; right: adequacy of time needed to play

Lastly, the game design was evaluated, considering all the elements that compose it: the board pieces, the pawns, the question and condition cards and the box. As previously mentioned, this game was designed to be visually appealing and familiar to its users, and it is quite important to understand if the game design follows that requirement. The participants generally found the illustrations very clear and helpful in identifying the different steps in the adhesive joint production process (see figure 15). However, the acceptance of the colour palette used was not unanimous and participants reiterate that there is a window for improvement of the selected palettes (see figure 15). When asked about the improvements, they explained that some tones were very similar which could generate some confusion between the cards and that in case of people with colour blindness it would be more interesting to use more friendly colours. The players considered the box design and the way the pieces are stored to be an asset, as it significantly reduces the space taken up by the game and allows it to be carried in a conventional backpack or bag.

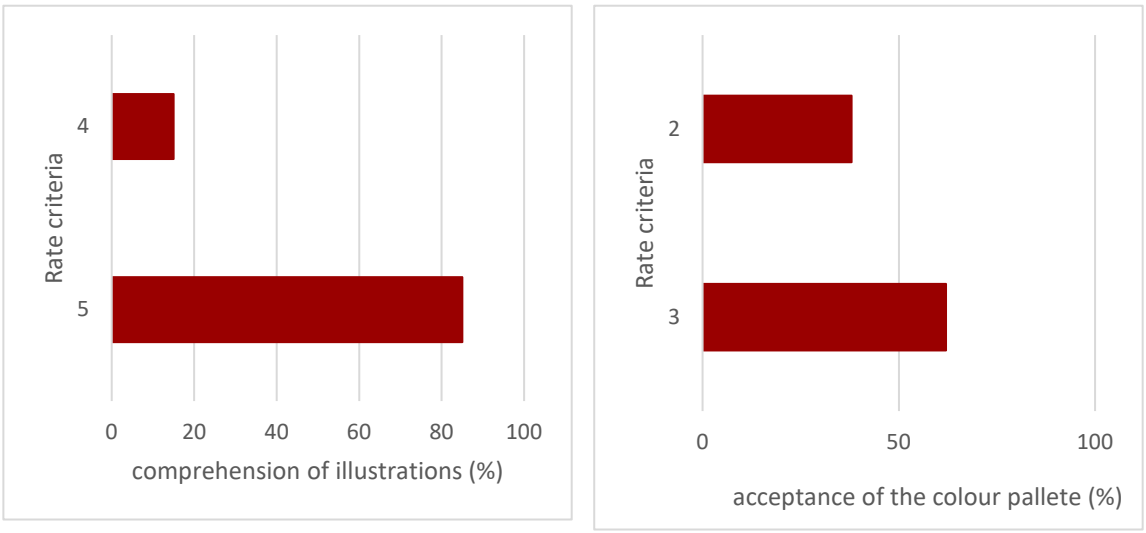

Figure 15 - Results of survey responses: left: comprehension of the illustrations of the used in the game (board and cards); right : acceptance of the colour palette used.

Besides the interpretation of the survey results, the impact on the final results of this course is another way to evaluate the implementation of this tool in the technical course where it was applied. The EAB course is evaluated by an independent evaluation committee and presupposes a written, practical and oral component. Trainees are assessed on questions similar to the questions in the game and the evaluation of hypothetical scenarios is one of the ways of assessing the practical component of the EAB exam.

In Portugal, the EAB course has already five editions and the average evaluation values of this course are shown in figure 16. By analysing these results, it can be observed that on average the final results are quite good. The second edition of this course was composed by elements with an excellent background in adhesive bonding technology, so the results are exceptionally good. Analysing the remaining results, it is observed that there is an increasing increase in the average value of the final evaluations throughout the editions. It should be noted that in the fifth edition of this course, when BONDER was applied, the average value is similar to previous years, but the standard deviation is significantly lower. In other words, there is a greater uniformity of the final evaluation value, regardless of the backgroup and educational level that the trainees had before starting this course.

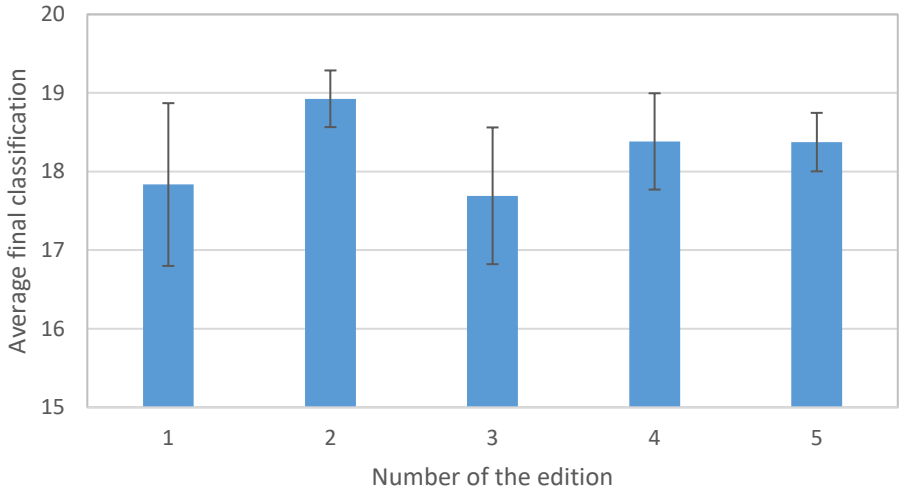

Figure 16 - Results of the average grade for the EAB course in Portugal

It is premature to say that BONDER had a direct effect on these results, since there are other variables that can compromise these results. However, it would be interesting to monitor this evaluation not only in future editions of the EAB course, but also in classes of engineering courses. A better way to evaluate the effect of the course would be, with a larger population, to observe the effect on the grades of students who had access to the game and students who followed the traditional didactic approach.

5. Conclusions

The Bonder game was fully developed and applied in two test sessions. Some conclusions can be drawn:

- The bonder was developed to be a tool for knowledge consolidation and by the results presented, there was a good acceptance as a didactic tool;
- The game has been developed to have an intuitive character design, with appealing and informative layouts. However, some responses regarding the acceptability of the colour palette were not so favorable, especially from male respondents, who presented some difficulties in identifying the colours.

- The vast majority of the respondents felt quite confident during the game and assumed that it was a good tool to consolidate the topics covered previously in class. Several reiterated that they would like to play again and preferred this approach to the classic revision questions.
- Although the initial results are quite promising, more test sessions will be necessary to fully evaluate the application of this didactic tool.
- In future work it would be interesting to internationalize this board game, since the need identified in Portugal is common to several countries, not only in the EU, but also in the rest of the world. In this way, it would be interesting to collect the training needs of several countries and adapt this game to their native language.
- Since there is currently a big commitment to digital learning tools, it might be relevant to lead this game towards digitalization. However, there would have to be a new approach to the game and not a direct transition of its elements, since the success of this game lies largely in the role of the Game Master.

Acknowledgements

The authors would like to express their gratitude for all the support provided by Tiago Gama e Gustavo Magalhães in the mentoring provided in the Emergence Science Communication Hackathon - 2022 edition.

References

Aburahma, M. H., Mohamed, H. M. Jajope. 2015. "Educational Games as a Teaching Tool in Pharmacy Curriculum." 79 (4).

Aebersold, M., Tschannen, D., Stephens, M., Anderson, P., Lei, X. J. 2012. "Second Life®: A New Strategy in Educating Nursing Students." 8 (9): e469-e475.

Barbosa, A., da Silva, L., Loureiro, A., Marques, E., Carbas, R., de Barros, S. J. 2021a. "European Adhesive Bonder: A Targeted Training for Portuguese Professionals Harmonized with European Directives." 7 (1): 37-47.

Barbosa, A. Q., Loureiro, A., da Silva, L., Almeida, A., Rosado, T., Casero, A., Meiβ, E., Balaska, H., Uran, M., Almeida, R. J. 2021b. "AdTech Project: European Harmonized Training System Focus on Adhesive Bonding Technologies." 1 (1): 133-149.

Boghian, I., Cojocariu, V.-M., Popescu, C. V., Mâţă, L. 2019. "Game-Based Learning: Using Board Games in Adult Education." 9 (1).

Braghirolli, L. F., Ribeiro, J. L. D., Weise, A. D., Pizzolato, M. J. 2016. "Benefits of Educational Games as an Introductory Activity in Industrial Engineering Education." 58: 315-324.

Cojocariu, V.-M., Boghian, I. 2014. "Teaching the Relevance of Game-Based Learning to Preschool and Primary Teachers." 142: 640-646.

Da Silva, L. F., Öchsner, A., Adams, R. D. 2018. "Introduction to Adhesive Bonding Technology." In Handbook of Adhesion Technology, edited by Springer, 1-7.

De Castell, S. 2011. "Ludic Epistemology: What Game-Based Learning Can Teach Curriculum Studies." 8 (2): 19-27.

Marques, E. A. S., Carbas, R. J. C., Akhavan-Safar, A., da Silva, L. F. M. 2021. Introduction to Adhesive Bonding. Wiley, Weinheim.

European Federation for Welding. 2015. AdTech - European Harmonized Training for Adhesive Bonding Technology. EWF.

European Federation for Welding. 2019. EWF Guideline European Adhesive Bonder - Minimum Requirements for the Education, Examination and Qualification EWF-515r2-19. EWF.

Fitzgerald, K., Bartlett, M. J. 1997. "Instructional Methods: Selection, Use, and Evaluation." 26186.

Henderson, D. J. 2005. "Games: Making Learning Fun." 3: 165.

Hinebaugh, J. P. 2009. A Board Game Education. R&L Education.

Ingalls, J. S. 2018. "Improvisational Theater Games: Performatory Team-Building Activities." 89 (1): 40-45.

Jones, A. M. 2003. "The Use and Abuse of PowerPoint in Teaching and Learning in the Life Sciences: A Personal Overview." 2 (1): 1-13.

Manion, K., Nixon, P. 2012. "Listening to Experts: Children and Young People's Participation." 49: 30-39.

Mora, S., Fagerbekk, T., Di Loreto, I., Divitini, M. 2015. "Making Interactive Board Games to Learn: Reflections on AnyBoard." In Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn), 29.

Penciner, R. J. 2013. "Does PowerPoint Enhance Learning?" 15 (2): 109-112.

Rugelj, J., Jedrinović, S., Bevčič, M. 2018. "A Comprehensive Model of a Cooperative Role-Playing Game." Wip.

Schwichow, M., Zimmerman, C., Croker, S., Härtig, H. 2016. "What Students Learn from Hands-On Activities." 53 (7): 980-1002.

Sousa, M., Bernardo, E. 2019. "Back in the Game." In International Conference on Videogame Sciences and Arts, 72-85. Springer.

Treher, E. N. 2011. "Learning with Board Games." JTLKI.

Tufte, E. R. 2003. The Cognitive Style of PowerPoint. 2006. Graphics Press, Cheshire, CT.

Wilson, K. A., Bedwell, W. L., Lazzara, E. H., Salas, E., Burke, C. S., Estock, J. L., Orvis, K. L., Conkey, C. 2009. "Relationships between Game Attributes and Learning Outcomes: Review and Research Proposals." 40 (2): 217-266.

Zalka, C. V. 2012. "Adventures in the Classroom Creating Role-Playing Games Based on Traditional Stories for the High School Curriculum."