Game Modding for Learning Design Thinking on an E-Learning Platform

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ABSTRACT

Design Thinking (DT) is not merely a well-known design methodology but also an entire mindset towards solving complex societal problems in an innovative way. Its popularity in diverse disciplines beyond design, is due to its relation with the development of key 21st-century skills, such as creativity, critical thinking, collaboration and communication. Teaching the DT mindset has always required methods different from the traditional, one-way, mainly teacher-led approaches in which students play a more passive role in the learning process. Such creative methods include constructivist teaching practices, such as learning-by-doing and learning-by-making. Game modding, which is defined as the modification of existing games, is also seen as a constructivist teaching approach since in this way students learn by designing a game. The experience is argued to increase the engagement and interaction of players with the game, and combine the roles of player and designer. However, using game modding to teach the DT mindset remains poorly researched. This paper discusses the outcomes of a pilot study developed in the scope of the in-progress Erasmus+ KA2 project 'T-CREPE' (Textile Engineering for Co-Creation Paradigms in Education). This study investigates the influence of game modding on students' adoption of the DT mindset through the use of an online learning platform that enables a game modding experience. This platform includes games that students can play, modify, and/or design their own in the process of developing a project. Students (n = 240) and teachers (n = 9) from three higher education institutions in Belgium and Greece participated in this study. The quantitative and qualitative data collected has provided information on their experiences of game modding while cultivating a DT mindset. The findings of the study indicate that game modding enables students to practise critical questioning, constructionism and co-creation, which are core elements of the DT mindset.

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INTRODUCTION

Design Thinking (DT) provides a human-centred base to examine and reframe interdisciplinary or unfamiliar problems to find innovative solutions. The term "wicked problems" coined by Horst Rittel, refers to these complex problems that stem from multiple causes, and affect a multitude of stakeholders with various needs that do not have a single solution (Rittel & Webber, 1973; Buchanan, 1992). For this reason, wicked problems, first, cannot be solved by following a conventional engineering-grounded linear process, and second, they require the involvement of the stakeholders, who have a connection with, and are affected by the problem. The DT methodology approaches these problems from a possibility-driven, iterative and continuous perspective. In order to achieve solutions that meet the needs of individuals, it encourages empathising and strives at involving the users in co-creation (Liedtka et al., 2013). Moreover, it advocates the importance of hands-on activities linked with real-life issues rather than hypothetical projects (Dorst, 2010; Liedtka et al., 2013). Although these are the most well-known properties of DT, there is not only one clear definition for this framework. In fact, DT is often criticised because of the lack of consensus on an appropriate definition (Kimbell, 2011; Thao, 2016). Since DT has been adapted and used by multiple disciplines, it can carry a different meaning in accordance with the field which it is utilised and the practitioners' interpretation.

Moreover, according to recent developments in theory, DT is not only a process but also a mindset (Dosi et al., 2018), and its essentials are *human-centeredness* (Liedtka, 2011), *empathy* (McDonagh & Thomas, 2010), *co-creation* (Liedtka et al., 2013), *multidisciplinary approach* (Meinel & Leifer, 2012), *critical questioning* (Davis, 2010) and *learning-by-doing* (Schweitzer et al., 2016). Brown (2008) explains the key characteristics of the DT mindset as: 1) *empathy* (trying to look at the world from multiple perspectives); 2) *integrative thinking* (transcending analytic thinking); 3) *optimism* (hoping there is at least one alternate solution for challenges); 4) *experimentalism* (exploring the limitations through creative ways that lead to innovation); and 5) *collaboration* (to be able to work in interdisciplinary settings and have experience in more than one discipline). According to some researchers (Baeck & Gremett 2012; Luka, 2014; Guvenir & Bagli, 2019), the DT mindset has nine characteristic features: 1) *ambiguity*; 2) *collaboration*; 3) *constructiveness*; 4) *curiosity*; 5) *empathy*; 6) *holism*; 7) *iteration*; 8) *non-judgmental way*; and 9) *openness*. Even though there is not one single definition of the DT mindset either, cultivating it in individuals is regarded as the key to face today's and future's manifold world challenges. Hence, it is of paramount importance to support the improvement of approaches and tools that can ameliorate the DT learning process (Fabricatore & Lopez, 2018).

Customarily, the DT methodology has been utilised and taught both in academia and professional practice (IDEO, 2021) in numerous disciplines besides the design domain (Gill & Graell, 2016), including marketing (Chen et al., 2018), business (Gaskin & Berente, 2011), management (Ramaswamy & Ozcan, 2018), education (Torrisi-Steele, 2020), and medicine (Badwan et al., 2018). Previously, in order to teach the DT methodology and mindset, unconventional and creative techniques have been employed to address the non-linear, ill-structured and iterative nature of the design process. For instance, constructivist learning strategies, such as learning-by-doing, learning-by-making (Morado et al., 2021), and collaborative learning tools, namely the Think-maps (Oxman, 2004), have been used in order to teach DT effectively through the active involvement of learners. Starting from this standpoint, the game-design strategy - as another approach in constructivist learning - could also be a useful tool for DT learners and educators. However, a lack of association between the game-design approach and teaching the DT mindset is being reported (Cooke et al., 2020). Only a limited number of researchers has stated that games can be utilised for teaching DT (Tsalapatas et al., 2019). Nevertheless, these studies have not presented a connection between game-design and the DT mindset. For instance, the DT mindset has not been linked before to game-design as its learning outcome.

However, students' active involvement in the learning process is not new. This has been discussed and the significance of learner-generated contexts has been pointed out by various researchers (Luckin et al., 2007, Aguayo et al., 2017). Students' transition from consumers to producers has been also linked with participatory design, which advocates the involvement of the people who will be affected by the outcome in the design process (Ehn, 2008). These create a broader framework for the use of game modding (Hong, 2013; Kafai & Burke, 2016) in DT education.

Game-based learning refers to using games to make the learning activity more engaging, motivating and efficient (Plass et al., 2019). Kafai (2006) explains that educators can approach the exploitation of games for learning from two points of views: **instructionist** and **constructionist perspectives**. In the instructionist approach, students only play the games as passive consumers. Differently from instructionists, constructionists encourage their students to create and design their own games as active participants. In line with the constructivist learning principles, several researchers advocate that designing their own games (**game-design approach**) offers students a more enriched learning experience when compared to merely playing games for learning (Yiannoutsou & Avouris, 2012; Kafai & Burke, 2015; Kynigos & Yiannoutsou, 2018). Kafai and Burke (2016) point out that the **game-design approach**, in

which students design their own games, encourages students' transition from being passive consumers towards becoming active producers and participants.

However, one of the biggest obstacles for incorporating game-design approach into education is that it may require high technical knowledge of the students. In this case, game modding can be seen as the solution as the initial step of game-design. **Game modding** is a term that comes from the gamers' communities and describes the process of players modifying or extending **specific parts** of an existing game as a way to express personal ideas on how these parts should have been (El Nasr & Smith, 2006). Modifying games increases the engagement and interaction of players with the game (Sihvonen, 2011) and combines the roles of player and designer (Kynigos & Grizioti, 2020). Game modding has lately been used as an educational activity to support constructionist learning in different school subjects (Sotamaa, 2010; Kafai & Bruke, 2015), as well as, for engaging students with complex real-world problems (Grizioti & Kynigos, 2021). One of the advantages of game modding, compared to game-design, is that it involves students in a progressively constructing process (El Nasr & Smith, 2006; Sotamaa, 2010; Kynigos & Grizioti, 2020) in which they play, discuss and build on an existing game, instead of creating all the elements of a new game from scratch. This allows users/players who are not experts in programming and game-design to express their ideas, create and share new game versions, and in a way, become part of the game development and improvement. One design construct developed to promote learning through game modding is the design of the **'half-baked' games**, which are purposefully faulty or inadequate aiming to provoke students to question and modify them (Kynigos & Yiannoutsou, 2018). Half-baked games have been created and used in digital platforms that allow users to easily modify parts of the game with high-level computational affordances, in our case, the ChoiCo (Choices with Consequences) environment. In these environments, students do not have to think about the technical details of creating a game because it is relatively easy to make changes even for novices or individuals from disciplines irrelevant to programming disciplines. Hence, they can focus on and modify the values, axioms, rules and meanings given in the game (Grizioti & Kynigos, 2021). Moreover, half-baked games can raise awareness and questions and start discussions among students with their function in promoting game-design.

As can be inferred from the literature, game-based learning, game-design and game modding approaches have been utilised especially in teaching complex and diverse subjects, such as programming, mathematics, and linguistics in order to enhance student involvement, enjoyment and commitment (Squire, 2003). Even though these could be very beneficial in teaching the DT

mindset as well, especially to the 'outsiders' to design or novices in design education, this subject remains under-researched. The key research question of this study addresses whether and how game-modding approach affects the students' acquisition of the DT mindset.

CASE STUDY WITH THE 'PLANET' PLATFORM

In order to investigate the impact of game modding on students' understanding of the DT mindset, a case study was conducted in three university-level courses, one in Belgium and two in Greece. In this study, students from different disciplines including industrial design engineering, psychology, business economics, textile engineering and educational sciences utilised a learning platform in their courses. This was an online, student-centred, open-source platform, referred to as the 'Planet', developed in the scope of the Erasmus+ KA2 project 'T-CREPE', with the aim to remediate the learning of the DT methodology and mindset.

The platform (cocreationplanet.eu) conceptualises the DT methodology onto an imaginary planet with four continents that correspond to the four stages of this methodology: Discover, Define, Develop and Deliver, as modelled in the well-known 'Double Diamond' diagramme by the British Design Council (Design Council UK, 2021). However, this is not the only model and the Design Thinking process has been interpreted and adapted by various researchers and institutions (Stanford d.school, 2021; IDEO, 2021; Liedtka & Ogilvie, 2011). In all models, divergence (generating choices as much as possible) and convergence (making choices amongst multiple options) exist. Moreover, they have a problem space and solution space. Lastly, all models highlight the significance of iterations. In this study, the Double Diamond model of Design Council UK was preferred because of its comprehensiveness and simplicity. For instance, the Empathise stage of the Stanford's Design Thinking model is visualised as a first step in its 5-step diagramme, while in the Double Diamond it is part of the first, 'Discover' stage in the 4-step Double Diamond model The design of this platform was framed by the principles of constructionism according to which new knowledge is constructed by students when they collaboratively built public digital artefacts (Papert & Harel, 1991), and by game-based learning, game modding and game-design approaches (Prensky, 2005).

Each continent in the platform (Figure 1) represents the four DT stages; Discover, Define, Develop and Deliver (Design Council UK, 2021). The countries (Figure 2), or rather the name of those countries in these continents (e.g., empathising, exploring) stand for the 'concepts' educators would like to teach their students (e.g. empathy). Zooming in those countries, the cities (Figure 3) are the practical 'tools' that students can use to learn about these concepts. For instance, the Discover continent includes the Empathise country, where there
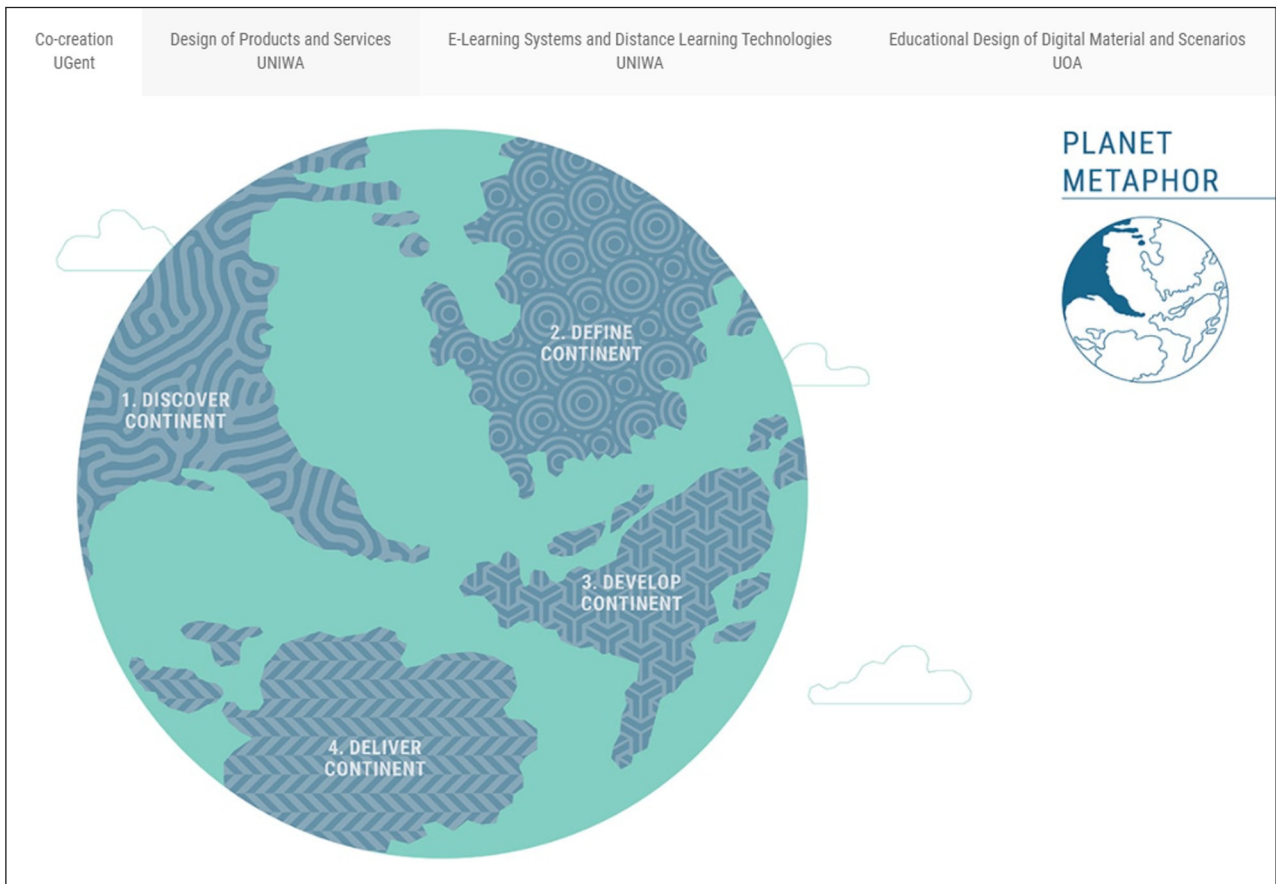
Figure 1 The 4 continents of the Planet platform as the 4 stages of the DT methodology.
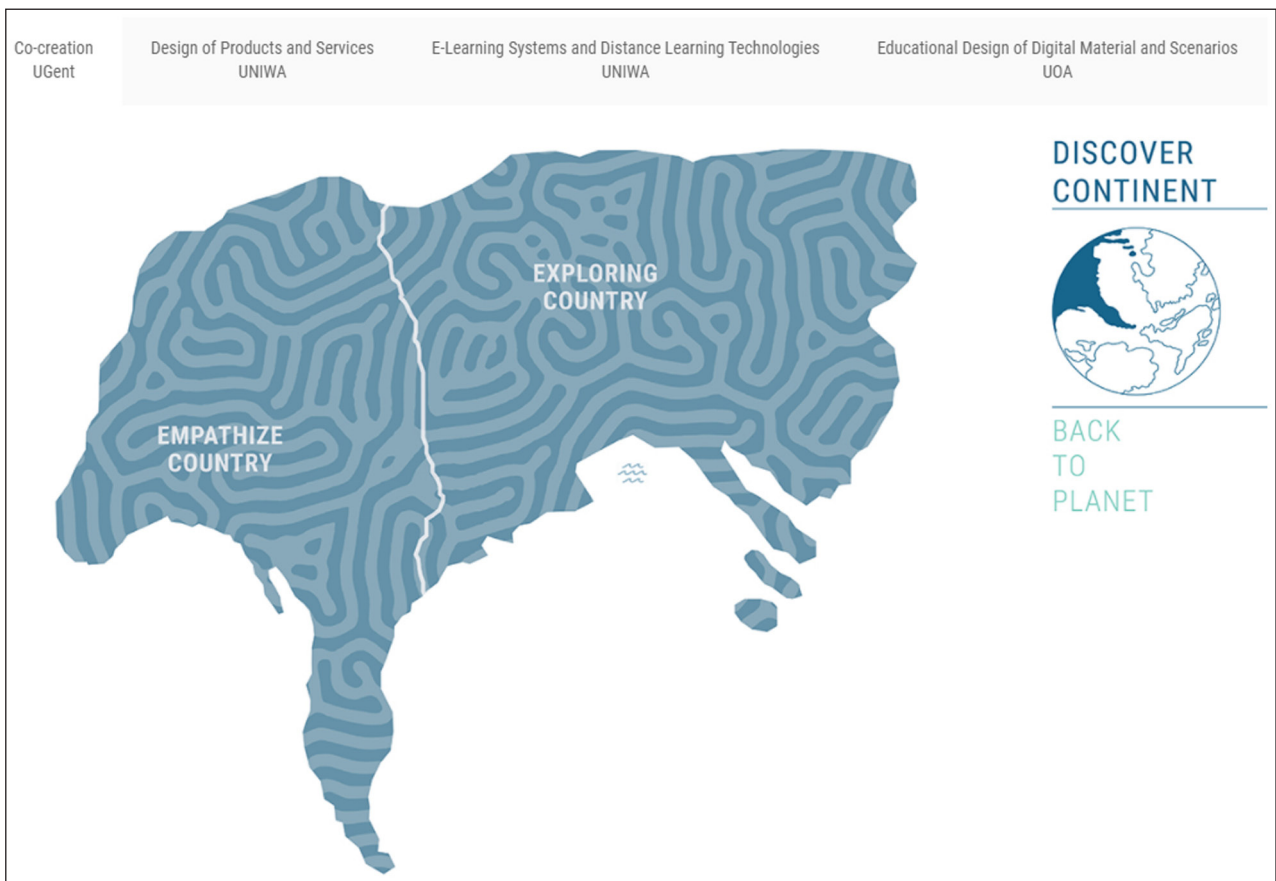

Figure 2 Countries that represent 'concepts' in the Discover continent.
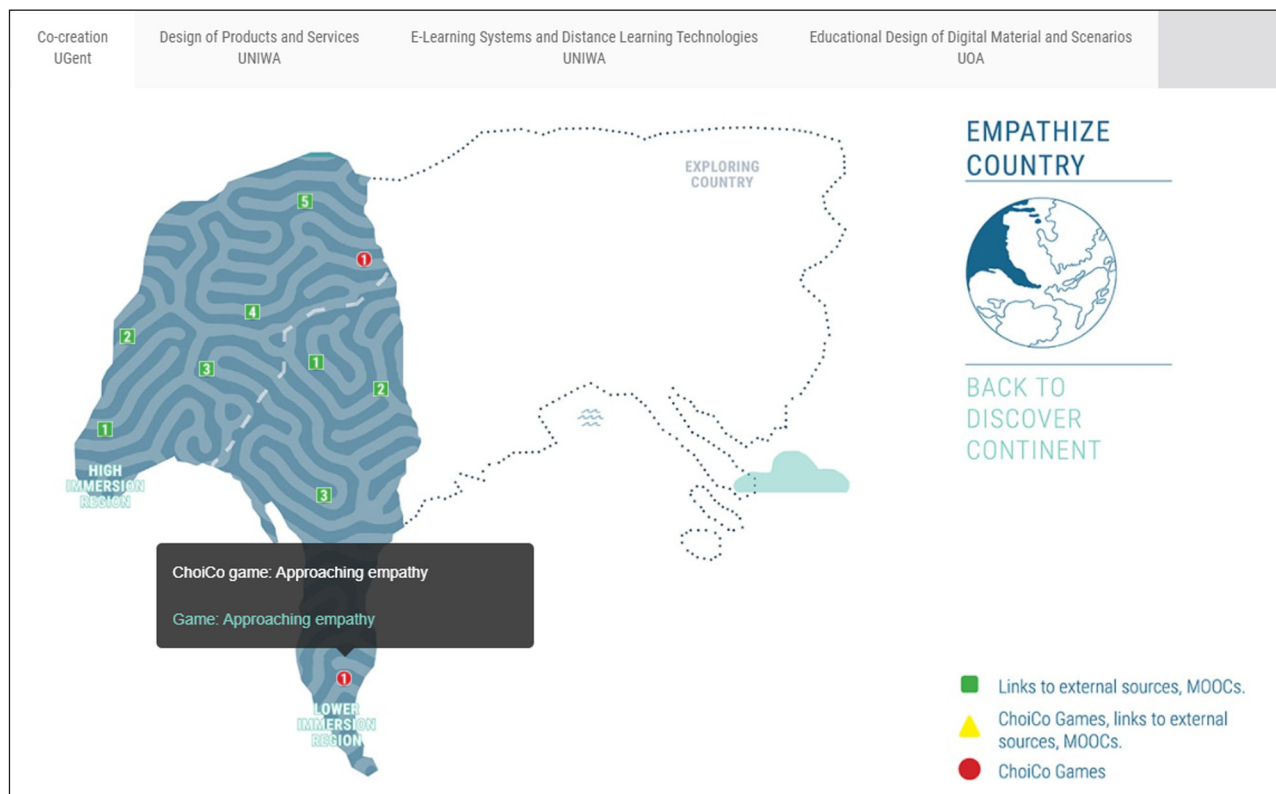
Figure 3 Cities as tools that include links to external and internally-made sources (e.g. ChoiCo games).

are 'tools' that are external resources, such as TED Talks on empathy, an interview guide, and also, internally-made resources such as the ChoiCo game called "Approaching Empathy".

ChoiCo (Choices with Consequences) games are included in the platform with the aim of enabling students, who are working on individual group projects for their courses, to explore and develop an understanding of the DT methodology through game-based learning, game modding and game-design approaches. Kynigos and Grizioti (2020) define "ChoiCo" as an open-source, online authoring tool that provides an opportunity to play, design and modify choice-driven simulation games related to complex real-life issues. In these games, the player navigates through different map-based areas making choices that affect the game parameters (e.g. Money, Health, Fun etc). The aim is to keep making choices without any of the game parameters crossing certain "red lines".

The ChoiCo games have two modes: play mode and design mode. In the play mode, students play the game trying to keep the balance of the game parameters for as long as possible while making choices. In the design mode, students are able to modify parts of the game, including its parameters, choices, ending conditions, graphics and data, by using high-level tools like block-based programming and a database. In this way, they have the opportunity to express their ideas on the game content and develop their own understanding and knowledge of its values.

This study focuses on the design mode of the ChoiCo games and its impact on students' understanding of the DT methodology and adoption of the DT mindset. For this reason, the next section explains how game modding can be possible in ChoiCo games and what can be changed through the design mode.

GAME MODDING WITH THE CHOICO GAMES

According to its definition, the ChoiCo games are not developed for close-ended topics. Instead, they are open to modification, adaptation and manipulation. Hence, they are designed in a way that provides individuals an opportunity to make changes in the game and even create a totally new game. Therefore, ChoiCo games do not only offer a 'game play' mode, but also a 'design game' mode (Kynigos & Grizioti, 2020).

As an example, Figure 4 demonstrates the play mode of the ChoiCo game interface of the "Approaching Empathy" game which is located in the Develop continent and the respective Empathise country of the planet platform. The interface of this game consists of parameters (e.g., allocated time, effort), initial values (e.g., 40, 100), a background image, choices (e.g., "Observe users at countryside") and 'consequences' values. In a ChoiCo game, each choice has certain scores in given parameters, which may depend on the topic of the game, and these are represented as 'consequences' values on the right-hand side of the game interface.

The design mode of the ChoiCo games offers affordances for changing all these game elements (parameters, initial values, background image, choices and their 'consequences' values), as well as game-play
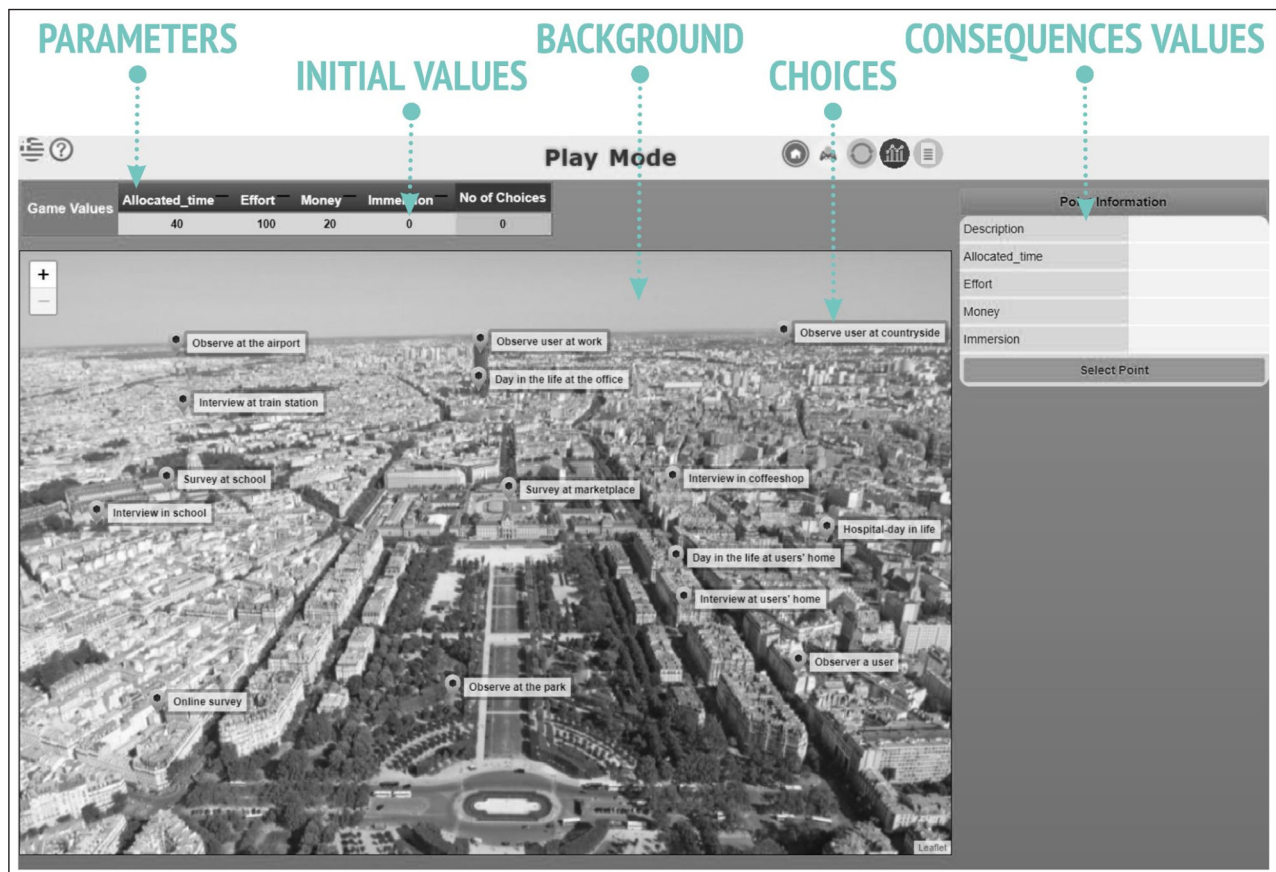
Figure 4 Introduction of the ChoiCo game elements (http://etl.ppp.uoa.gr/choico/).

rules and end rules of the games. For instance, students can determine what will be written on the pop-up window that will appear when the players are below certain scores in order to warn them and attract their attention towards other parameters. Furthermore, they can also change the scores in conditional statements (e.g., if immersion is lower than –20 then the game is over). Depending on the topic of the ChoiCo game, students are encouraged to modify all values and other game elements via the design mode.

This study focuses on the design functions of the ChoiCo games that give students the chance to make changes in the games according to their course projects. In this way, this research aims at investigating the impact of game modding on the adoption of the DT mindset. The following section explicates the methods used in this pilot study.

METHODS

In this pilot case study, the planet platform with the ChoiCo games was implemented in a one-year long 3rd-year bachelor design engineering course in Belgium during the 2020–21 Fall and Spring semesters, a 2nd-year bachelor industrial design and production engineering course in Greece, and a Master's-level educational sciences course in Greece during the 2020–21 Spring semester. All these courses were project-based courses

and the students worked in groups with their classmates. Each group of students were working on a specific project (e.g., women's role in modern society, minimal tap water consumption in Belgium) and the planet platform with its ChoiCo games were integrated into their course as a complementary tool for supporting the learning of the DT methodology and acquisition of the DT mindset. Since all these courses were project-based courses in which students deal with societal real-life problems, ChoiCo games were easily adaptable to these contexts such as tap water consumption. Moreover, these games were found suitable in these courses because via its game modding feature, ChoiCo provides a chance to simulate complex real-life issues, namely "wicked problems". Also, through this pilot study, the effectiveness of game modding on students' acquisition of the DT mindset throughout the courses was investigated using the "Design Thinking Mindset Questionnaire" (Dosi et al., 2018).

Both quantitative and qualitative methods were utilised in order to elicit data and information regarding the experiences of students and course teachers with the planet platform, ChoiCo games and game modding. Students (n = 240) filled out a questionnaire before and during their experience with the ChoiCo games. This quantitative data was supplemented with students' (n = 113) self-reflection reports and semi-structured interviews conducted at the end of the semester with both teachers and students.

A template for self-reflection reports was prepared by the researchers and distributed to the students at the beginning of the semester. The students filled in the reports as a "journal" just after they played/designed a game or used a tool in the planet platform. Semi-structured interviews were conducted on a voluntary basis with students and teachers at the end of the semester after their interaction with the tools and games. Students from 6 different project groups (out of the total 40 groups) who modified the games (n = 8) were interviewed (on a voluntary basis) regarding their game modding experiences. The interviews were conducted online through Zoom. The questions asked during the interviews were about students' opinions on game modding, their gains from it in relation to learning about the DT methodology and mindset, and the acquisition of certain skills during game modding from their perspectives. Moreover, students were asked to show and explain the outcome of their game modding experiences (their game design) by sharing their screens during the online interviews.

The aim of this research project and the expectations from students and teachers as participants were explained at the beginning of the semester both verbally and in text, and their questions were answered. At the start of the online questionnaires, the participants read a text about informed consent. The ones who would like to take part in this study agreed and continued with the rest of the questions. In order to protect students' rights, no real names were disclosed and pseudonyms were used on the transcripts of the interviews and in the manuscript.

The data collected through these qualitative and quantitative methods were analysed on NVivo 12, a qualitative data analysis software. Students' comments on the reflection reports open-ended questions of the questionnaires, and interviews were coded through thematic analysis. Table 1 demonstrates an example of how students' comments are linked with the themes. The codes were generated following both an inductive and deductive approach (Saldaña, 2013). The codes about game modding (changing only the game elements, adding new elements and creating a new game) defined by the researchers (deductive approach). The other codes, namely improving critical thinking skills, were created simultaneously while reading the students' comments (inductive approach).

RESULTS

The findings of this pilot study provided an insight into students' motivations for modifying the games and their gains from this experience with regard to the DT methodology and mindset. According to the results of the questionnaires, interviews and self-reflection reports, students' motivations to modify the ChoiCo games in the planet platform stem from various reasons. This section covers the game modding experiences at various levels (e.g. changing only the game values, adding new elements, creating a new game) of the students that originate from different motivations, and the gains of the students from game modding in relation to the DT methodology and mindset.

STUDENTS' GAME-MODDING LEVEL

Since the students shared their screens during the online interview and demonstrated the changes made by them, it was possible to see how, why and what sort of modifications are made by the students. The modifications of the students can be grouped under three main sub-categories from micro (small changes) to macro (fundamental changes) level changes: changing only the game values (Level 1); adding new elements (Level 2); and creating a new game (Level 3).

Level 1: Changing only the game values

Several students stated that they did not change the parameters but they manipulated the game values given in these parameters. For instance, in the "Impact of Empathy" game, which is located in the Discover stage on the planet platform, the aim is to empathise with diverse user types as much as possible and try to look at the issue from the perspectives of these users. The user

CODES	STUDENTS' COMMENTS
Improving critical thinking skills	"Specifically it improved my critical thinking skills because you start to question the methods that you employed in the project. So you start thinking 'Oh wait, maybe we could do it otherwise!'"
Creating a new game	"My team and I worked together to make a ChoiCo game, the main idea was to make the player make decisions about the parts that he would want on his own e-scooter to possess. He has seven categories from which he can choose from different types of components for his e-scooter. Every component has three values on it, price, weight and durability. Once the player completes all seven categories he is going to be presented with a message. If the choices he made were correct (meaning the e-scooter was not too expensive, heavy or unstable) the message will say: "You did it!", but if the choices weren't so wise the message will say: "You failed!". Regarding the game making experience, I personally found our game quite enjoyable and fun, it took us some trial and error to figure some stuff out, but in the end everything blended together perfectly. It was a really amazing experience, all the members of the team were friendly and hardworking.'

Table 1 An example from the coding process with NVivo 12.

types are given as parameters in this game: 'youngsters', 'elderly people', 'non-natives' and 'people who have low income'. The choices that students can make in this game range from high-immersion research methods, such as "interview at users' home" to low-immersion ones, namely "do an online survey".

In this example, one of the students explained that they did not change the parameters but they modified (Figure 5) the game values, which are the scores of the choices. What motivated this student to modify these numbers derives from the idea that they believe that the given game values were not correct from their point of view. Another student expressed that they made changes in the game values since they found the game too easy and wanted to make it more challenging. This can be seen as a micro change and the first level of game modding, since only changing the game values does not require a lot of effort and a complex thought process of the students. However, it still shows that students critically approached these games.

> "I think the working class is part of the elderly and this group is a major part of commuters, so I changed their score from –10 to 10 for an interview at the station." - *Student 1, reflection report*

Level 2: Adding new elements
In this pilot study, the second level experienced by some students in game modding included adding new elements to the ChoiCo games. It was found that some students not only changed the initial or 'consequences' values but also went a step further and generated new parameters, game play rules, end rules and choices for their games.

> "I decided to add a new point called 'interview at tourist destination'. Here the score for youngsters remains neutral, the elderly and non-natives get respectively a score of 10 and 15. Low-income

people get a score of 2." - *Student 2, reflection report*

This modification necessitates students to go through a meaning-making process at a higher level rather than only changing the game values. One of the aspects that motivated students to add new elements in the ChoiCo games is explained as *exploring the games*. The students mentioned that they tinker with the games in order to see the impact of these changes on the game.

Another source of motivation for the students in generating new elements was *improving the quality of the game*. For instance, some students modified the end rules of the ChoiCo games in order to prevent the game from ending too quickly or have more realistic results from the game.

Level 3: Creating a new game
As the last and macro-level of game modding, some students designed their own games. Since game modding does not require high-level programming knowledge, students were able to create new games in a more convenient way.

The students, who created a new game, noted that the reason for them to engage in this activity was making the game more aligned with their course projects. This means that the students used the opportunity to create a new ChoiCo game in relation to their course project topics. In some cases, if the existing game is relevant to the course project of students, it motivated them to further develop and modify it.

> "I saw alignment with my project, I saw potential in modifying it and I could get the value out of it. Seeing initial alignment with your project is really useful to actually make sure that you start modifying it. Because otherwise, I think that the possibilities are slim to none that you are going to modify it if you don't see alignment." - *Student 3, interview*
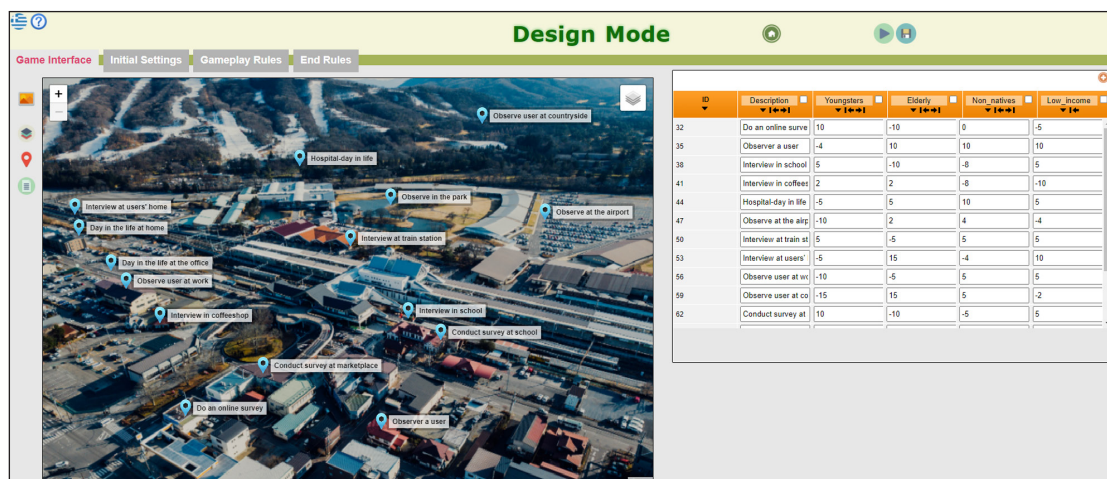

Figure 5 Impact of Empathy game design mode allows students to change the game values on the right hand side.

For instance, a group of students designed a new game aligned with their project topic. Their course project was about the roles of modern women in today's society. They created game instructions that appear as the first message on the screen when someone enters the game. Their parameters were: 'wellness', 'family', 'career', 'socialising', and their choices were: 'entertainment', 'workout', 'cooking', 'maintenance', 'parent', 'child' and 'partner' etc. Figure 6 demonstrates that students changed the background image, game values, choices and their consequences and created a totally new game. In addition, they added a pop-out message that will be seen if the wellness level drops to –15 after making certain choices. The students explained that they created this game as a group during the course and the game modding function allowed them to discuss the values and meanings of the game topic among themselves.

STUDENTS' GAINS FROM GAME-MODDING IN RELATION TO THE DT MINDSET

The findings demonstrated that students were able to gain several skills during their game modding activity in this case study. This section presents the gains that can be associated with the DT mindset, namely, critical questioning, constructionism and co-creation.

It was found that during this study the students practised critical thinking and questioning in many ways with the ChoiCo games. Firstly, they became sceptical and they learned to question the existing game elements with the intent of improving or/and adjusting them, by exploring the game or expressing their own perceptions. Secondly, they were critical of their own choices through looking for relevant tools for their projects. Lastly, while working with their group members, they questioned

their suggestions and this created a thought sharing atmosphere with the rest of the group members.

> "Specifically it improved my critical thinking skills because you start to question the methods that you employed in the project. So you start thinking 'Oh wait, maybe we could do it otherwise!'" - *Student 4, interview*

Moreover, the students were able to construct their own knowledge through game modding in the ChoiCo games. The hands-on nature of the game modding activity assigned them to the role of active participants instead of passive listeners in the class. In that sense, they learned about the DT methodology and mindset by doing and actively taking part in the design process.

> "I think it is much more useful for example to modify two games than to play six games. Because you get a lot more out of just modifying two for example. Because actually when you modify you are going to think about it, you put time into modifying and it's not just a game that was pre-designed for you but it is your own game that you make yourself." - *Student 5, interview*

The findings also showed that the game modding activity facilitated the co-creation process among group members during the course. Since they worked in groups, they did not design or modify the game on their own. Instead, they collaborated during the process and they had to compromise on certain features of the game. Moreover, the platform encouraged the active participation of the users and other stakeholders in

Figure 6 An example of how students created a new ChoiCo game (background, game values, choices).

the DT process with the tools in it, such as conducting interviews and observations with real users or external partners from the industry. These enabled them to practise and improve their co-creation skills, which is vital in developing the DT mindset.

> "It's really fascinating to see the different approaches that I took compared to her. We really had to find a certain way to merge those two ideas together because they were both important." - *Student 6, interview*

DISCUSSION

According to the results of this study, students' motivations (Figure 7) for game modding depended on the level of the changes (micro or macro changes) they made. In the first level, only changing the game values, students' motivation came from their need to express their own perceptions of the values. In the second level, students added new elements into the game because they wanted to explore the game or improve its quality. Lastly, in the third level, students were inspired to create their own games, which is about a completely different topic, with the aim of adapting the game to their own projects. It was found that as the process of modding progresses from micro to macro level, game-design activity becomes more engaging for the students. Moreover, they could get the most out of the ChoiCo games when they designed their own games, which are tailored in order to make them more aligned with their project topics.

The ChoiCo games can be seen as a tool to promote the improvement of the DT mindset of the students. The rationale behind this interrelation is that these games consist of many parameters and choices, which requires contemplation on each of them for finding the balance for staying longer in the game. This is a problem-solving process, which does not have a single clear answer. The problems, which arise from multiple causes and have an impact on a multitude of stakeholders, are defined as "wicked problems". This resemblance denotes the relation between the ChoiCo games, which includes wicked problems, and the DT methodology, which was developed for solving those problems.

The play mode of the ChoiCo games contributed to the development of the DT mindset of the students. In addition to that, this study claims that the design mode of the ChoiCo games (game modding) provides more chances to learn about the DT mindset rather than merely playing the ChoiCo games. Below are students' three main gains from a game modding experience in terms of the development of the DT mindset.

First, the game modding option provokes students to question the existing game setting, values and elements. In this sense, students practise critical questioning, which is one of the key criteria for developing the DT mindset (Dosi et al., 2018). For example, especially for designers, it is essential to question the existing properties of products, services or environments in order to come up with a design idea that meets the needs of users in an innovative way, which has not been possible before (Dym et al., 2005).

Second, game modding allows students to construct their own understanding and knowledge, which is in line with the constructionist learning principles. While modifying the game elements, students engaged in "meaning-making" activities and learning-by-doing. This is essential in teaching the DT methodology and mindset as a hands-on approach (Hassi & Laakso, 2011; Morado et al., 2021). Koria et al. (2011) stress that during the DT process, which is an abductive way of thinking (Martin, 2009), individuals can create new knowledge only through exploring, experimenting and learning-by-doing.
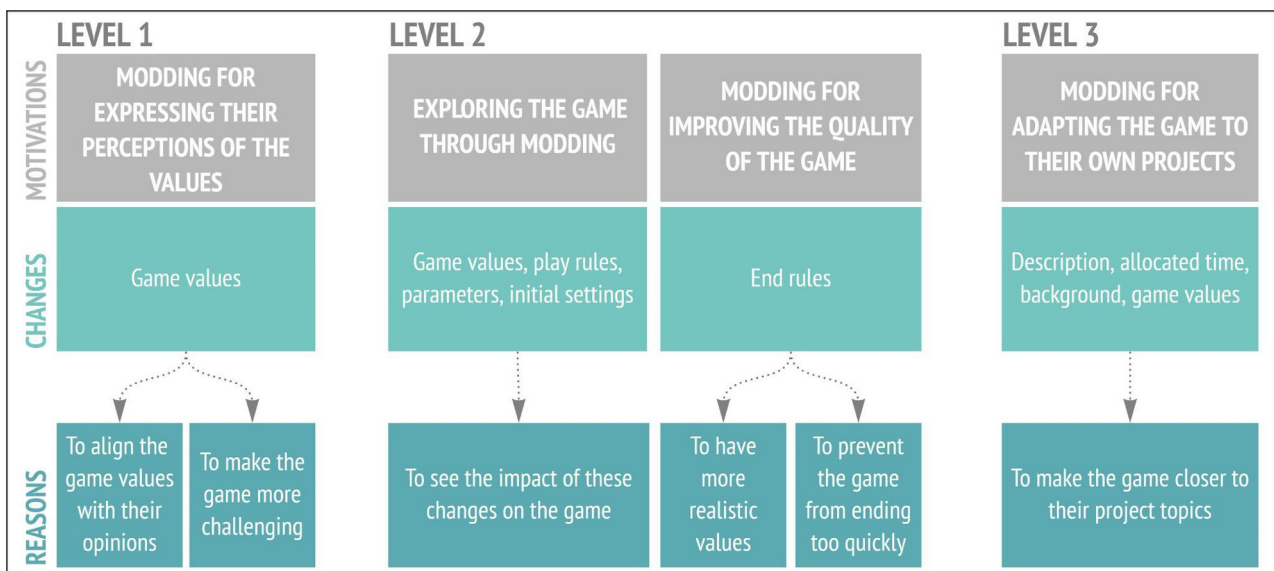
Figure 7 Motivations of the students for modifying the ChoiCo games.

Last, the game modding activity provides a basis for co-creation and collaboration. To be able to effectively work in a collaborative environment is crucial in reaching innovative solutions with DT and this is considered as the key driver in developing the DT mindset (Koria et al., 2011; Meinel & Leifer, 2012; Liedtka et al., 2013).

CONCLUSION

This in-progress study aimed to scrutinise whether and how game modding, as a way of game-design and constructivist learning strategy, affect students' adoption of the DT mindset.

Although not all principles of the DT mindset are covered in this study, game modding is still a promising medium in terms of contributing to the development of the core elements of this mindset. This does not mean that game modding has no impact on other characteristics of the DT mindset. The effect of game-modding on other DT principles can be investigated through further studies. Since DT is argued to be of importance in creating a more innovative future, it is vital to encourage students in learning about its essentials. For this reason, the use of an engaging, motivating, and effective tool, which is game modding with ChoiCo, has a significant role to play, and this is why it is offered as an additional tool to existing DT teaching methods. ChoiCo's high-level computational affordances, i.e. the database, the block-based programming and the map designer, seemed to motivate students to experiment with different game parameters and values, leading them to an in-depth investigation of the game topic. Moreover, adapting the games to their DT project's topic, like the example given in section 3.1.2., helped students to come up with solutions for their project which they probably would not have thought otherwise. Finally, the creation of a new game with the modding tools, like the example in section 3.1.3, enhanced their understanding of the socio-scientific issues they had to deal with and increased their sense of ownership of the game.

In conclusion, this study shows that game modding can contribute to teaching and learning about the DT methodology and developing this mindset in two main ways. First way is making students more conscious and critical of their choices through selecting and utilising relevant tools that enable them to better understand concepts they are dealing with in their design projects. The second way is allowing them to construct their own knowledge whilst co-creating with the game developers indirectly and their group members directly.

This pilot study is seen as a basis for redesigning the games and activities in order to perform a larger case study with more students. In the follow-up study, it is also aimed to investigate the relationship between game modding and other DT mindset principles that has not been found in this pilot study.

The findings of this study cannot be generalised because of the limited number of participants and the fact that it was a pilot study of a work-in-progress project in which many of its components were regularly revised and improved based on students' comments. However, they still show the potential of using game modding, game-design and game-based learning approaches for teaching and learning about the DT methodology and mindset. In this regard, this study may serve as a point of departure for further studies.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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