Every Lesson Needs a Gandalf: How Interactive Storytelling can Enhance the Collaborative Learning Experience!

Siem Buseyne, Chaja Libot, Tim van Lier, Annelies Raes

International Journal *of* Designs for Learning
2024 | Volume 15, Issue 2 | Pages 66-79

EVERY LESSON NEEDS A GANDALF: HOW INTERACTIVE STORYTELLING CAN ENHANCE THE COLLABORATIVE LEARNING EXPERIENCE!

Siem Buseyne[1,2,3], Chaja Libot[4], Tim Van Lier[4], & Annelies Raes[1]
[1]*KU Leuven, Faculty of Psychology and Educational Sciences;* [2]*KU Leuven, imec research group itec;*
[3]*Université de Lille, Centre Interuniversitaire de Recherche en Education de Lille (CIREL);* [4]*VRT*

Every teacher aspires to create the ideal lesson! You want to convey the knowledge and skills in the best possible way while also keeping learners motivated. In our design case, we focus on the complex skill of collaborative problem-solving (CPS). In today's complex world, the acquisition of CPS competencies is considered an important learning goal in education. However, there is limited knowledge on how to teach and assess CPS competencies. In addition to tackling these challenges, we search for new ways of interactive storytelling to implement in the learning materials. Our main design challenge was how to design a learning experience that encourages CPS. To address these challenges, we started in 2020 the project titled Supporting TEamwork in AMbient learning Spaces (STEAMS). In this project, we designed the EDUbox Teamwork, a four-hour learning activity for children between the ages of 10 to 14. In this paper, we describe the iterative process of designing the materials to learn about CPS (i.e., CPS as a learning goal) by doing CPS (i.e., CPS as a method), enhanced by interactive storytelling, for which the design-based research approach was used. The design team consisted of a diverse group of educational researchers, computer scientists, instructional graphical designers, digital storytellers, and teachers. Given the strong collaboration between a research group specialized in computer-supported collaborative learning and specialists in digital storytelling, our design case incorporated insights from both parties. The learning activity was piloted both in in-vivo and in-vitro contexts in collaboration with at least 400 students.

https://doi.org/10.14434/ijdl.v15i2.35644

Siem Buseyne is a Ph.D. researcher at Université de Lille (France) and at KU Leuven (Belgium). His main research interests are collaborative problem-solving and computer-supported collaborative learning, including the use of technology-enhanced learning spaces, multimodal learning, and classroom analytics.

Chaja Libot is a design researcher at the innovation department of VRT, the Flemish public broadcaster. She outlines the needs and wishes of users towards new technologies and products. She believes in Design Thinking as a methodology and applies it throughout projects during stages such as generating ideas, developing concepts, prototyping, and implementation.

Tim Van Lier is a digital product owner at the innovation department of VRT. He believes in the combination of technology, storytelling, and pedagogy. He is currently involved in different educational projects at VRT.

Annelies Raes is an Assistant Professor at KU Leuven within the Faculty of Psychology and Educational Sciences. Her main fields of interest are new innovative education models such as active learning and collaborative problem-solving and how this can be supported by emergent technologies. More specifically she is interested in the role of the teacher in technology-enhanced learning environments for complex learning.

INTRODUCTION

Today's society attaches increasing importance to teamwork, both in businesses and in formal education and training, due to fundamental transformations that are driven by technological and labor market developments. The future workforce must excel in activities that involve higher-order reasoning, decision-making, and social skills, as these skills are unlikely to be automated by artificial intelligence. This thinking is also reflected in a global trend in educational reforms that emphasizes the significance of transversal skills and key competencies (often referred to as '21st-century skills') such as collaboration, problem-solving, and creativity. The new Flemish educational standards for secondary education

(implemented in September 2019) have equally adopted this perspective. Students as well as employees in lifelong learning contexts need to learn more through collaborative problem solving (CPS) to stimulate active learning and co-creation of knowledge.

Although the value of CPS is widely recognized, successful teamwork is not guaranteed and can even be frustrating and harmful for learning due to freeriding, a lack of clear roles and responsibilities, or a lack of collaboration skills (e.g., Graesser et al., 2018). Additionally, educational practice lacks knowledge about how CPS can be best taught, supported, and objectively assessed.

In the summer of 2020, we therefore initiated a two-year lasting project entitled Supporting TEamwork in AMbient learning Spaces (STEAMS). One of the main aims of the project was to search for effective ways to foster students' CPS competencies, especially by adding different interactive storytelling ingredients as part of the EDUbox format (see Figure 1). This is a format of the Flemish public broadcaster (VRT). In this paper, we share our design journey which resulted in the EDUbox Teamwork, an interactive course to improve CPS competencies using various storytelling techniques and including evidence-inspired design guidelines.

FIGURE 1. Visualisation of the initial EDUbox format.

DESIGN TEAM & GOAL

The main members involved in the design of the EDUbox Teamwork were employees of the different partners in the STEAMS consortium. To design an EDUbox with a complex learning objective, CPS, several areas of expertise were required. More specifically, from the academic side, this mainly included members from itec, an interdisciplinary imec research group at KU Leuven, focusing on the design, development, and evaluation of personalized and adaptive digital solutions in application domains including education, training, and health. The itec members involved in the design of the course are educational scientists with an interest and expertise in computer-supported collaborative learning.

From the industrial side, the main partner involved in the design of the course was VRT. VRT wants to inform, inspire, unite, and reinforce the Flemish society. More particularly, VRT supports formal and informal education by collaborating with educational institutions. With the EDUbox, VRT has designed, since 2018, educational materials about contemporary, wicked, issues that usually require a transdisciplinary approach (e.g., artificial intelligence or democracy; see https://www.vrt.be/nl/edubox). The EDUbox concept aims to optimally stimulate imagination, participation, discussion, and tries to do this by integrating digital storytelling. Digital storytelling combines the art of telling stories with a mixture of digital media, including text, pictures, recorded audio narration, music, and video. As can be seen in Figure 1, the initial EDUbox format consisted of a physical box containing paper cards that guided the participants through the learning activities. Although the initial format already included a lot of multimedia elements (i.e., videos to support the digital story), no learning platform guided the activities which made it difficult for teachers to monitor students during their interaction with the EDUbox. Within the project, we aimed to add technological tools to create a "phygital" learning activity, optimally blending physical and digital components.

To create the (technological) tools supporting CPS, we partnered in the STEAMS project with Augment, a research group at KU Leuven that is specialized in Human-Computer Interaction; Averbode, a Flemish educational publisher; FTRPRF, a Flemish company building a learning platform for 21st-century education; and Hudson, a Flemish organization specialized in recruitment and selection.

Next to the industrial and academic partners, a collaboration was set up with three dedicated partner schools in Flanders to test the different parts of our course and to collect intensive feedback from teachers and students—as main end users—throughout the design phase.

DESIGN PROCESS BASED ON THE DESIGN-BASED RESEARCH METHODOLOGY

To guide and structure our design process and to reach our goal of designing a product that is highly appreciated by the end users, the design-based research methodology as described by McKenney and Reeves (2012, 2014) was used. This methodology is characterized by iterative cycles of analysis, design, and evaluation starting with small-scale pilots and ending with large-scale dissemination and, ideally, also implementation. In what follows we will describe our design process following the three crucial steps which are put forth in this methodology.

At the start of the design process, we first collaboratively reflected on our assumptions about CPS, both as a goal and as a method, drawing from the experience VRT had with their EDUbox concept and the expertise itec had based on the literature on computer-supported collaborative learning. The following assumptions were put forth: working together requires active learning activities; concrete examples are essential; the content may not be too abstract; assessment must be part of the learning experience; practice what you preach; and an overall story is needed. However, to be able to design the most effective activities, we felt the need to have a good understanding of the different dimensions of CPS competencies and the current challenges of fostering these competencies. In the first section, we elaborate on the problem analysis and the analysis of the current solutions to support CPS. Next, we describe the design of the EDUbox Teamwork. The third section describes the evaluation and reflection of the different versions of the EDUbox Teamwork, as the design of the EDUbox was an iterative process, in which many modifications have been made, considering problems and failures observed during the evaluation and reflection phases.

PROBLEM AND PRIOR SOLUTION ANALYSIS

Analysis of the CPS Curriculum

Our analysis of the current CPS curriculum consisted of three phases, based on the curriculum representations as defined by Thijs and van den Akker (2019). In our analysis we mainly focused on the ideal curriculum (i.e., the vision and rationale underlying the curriculum), the formal/written curriculum (i.e., goals described in curriculum documents or other materials), and the operational curriculum (i.e., the teaching and learning process). We did not focus on the two aspects of the attained curriculum (i.e., the learning experiences and outcomes), neither did we explicitly take into account aspects of the perceived curriculum (i.e., how teachers interpret the intended curriculum).

The ideal CPS curriculum

Our first step into the CPS curriculum analysis was looking into the underlying rationale for education on CPS as a goal, what it entails, and its importance in society.

Based on several policy and research documents, we concluded that competencies related to CPS are getting increasing attention. UNESCO (2015), for example, mentions that "beyond mastering work-specific skills, emphasis must be placed on developing high-level cognitive and non-cognitive/transferable skills, such as problem-solving, critical thinking, creativity, teamwork, communication skills, and conflict resolution, which can be used across a range of occupational fields" (p. 43). This is also in line with the future of in-demand work skills as discussed by the World Economic Forum (2020).

An important source of information on CPS is the PISA report of OECD (2017). In this report, CPS is defined as someone's capacity to "effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills, and efforts to reach that solution" (OECD, 2017, p. 134). Furthermore, based on the literature, we identified that CPS as an educational method is complex and does not always reach its full potential. This is due to many factors, including task characteristics, medium, problem scenarios, team composition, etcetera. The instructor's choices and competencies also play an important role.

Flemish curriculum and policy documents as a starting point

After having explored the concept of CPS in more detail, we investigated the Flemish curriculum documents, to find how and to what extent CPS as a goal was already implemented in the formal curriculum. This includes the learning goals as defined by the government.

One of the most important documents we identified is the Masterplan of the reform of secondary education in Flanders (see www.onderwijsdoelen.be). In this document, it is stated that Flemish students score poorly on social and citizenship competencies compared to their international peers. In the past years, a new curriculum has therefore been designed including sixteen key competencies, also referred to as transferable skills. Two of those sixteen key competencies are strongly related to the CPS competencies.

The first one, learning competencies including research competencies, innovative thinking, creativity, problem-solving and critical thinking, systems thinking, information processing, and collaboration, focus on the quickly evolving society in which students need to master a variety of strategies to steer and adjust their learning processes. Those competencies are necessary to acquire new knowledge and skills, as well as solve problems in many learning situations. The second key competency related to CPS is the

social-relational competency which focuses on building, maintaining, and empowering interpersonal relationships. In those types of relationships, individuals are interdependent, influencing each other's comportment.

However, the existence of these objectives does not necessarily imply that the implementation of these objectives is evident for and consistent between schools. This became clear in the interviews which we conducted as part of the needs analysis described in the next section.

Needs analysis based on surveys and interviews with stakeholders

How is CPS currently taught across various contexts, and what can we learn from the current way of working? Which aspects work well, and which aspects can be improved? These were the main questions we had concerning the operationalized curriculum (i.e., the way teachers translate curriculum goals into practice). We also wanted to get a better insight regarding if and how teachers use CPS as a method. To get to know the needs of our stakeholders, we sent out a survey to different schools. The survey was distributed widely across different education levels in Flanders. More specifically, 318 secondary school teachers responded to the survey. In addition, eight in-depth interviews were done as visualized in Figure 2.

The survey results revealed that most teachers are convinced about the added value of investing in CPS in education (88%), yet a large group of teachers also reported having difficulties when implementing CPS as a method, especially in monitoring and assessing the quality of collaboration during CPS (52%).

Teachers expressed that the integration of collaborative learning as a goal in practice was limited, although collaborative learning as a method is already largely implemented in different ways. On the one hand, there is collaborative learning as a method with generally short, focused periods of collaboration (e.g., in pairs). This type of collaboration is mostly very targeted and aimed at reaching a goal unrelated to the collaboration itself (such as, for instance, practicing the pronunciation of foreign words in pairs). On the other hand, collaborative learning is also used in a typically longer form, in which collaboration itself is an important aspect of the work needed to accomplish the goal (e.g., collaboratively constructing a science project. We found that only some of the teachers regularly use this more elaborate type of collaboration.

This finding was also reflected by the interviews: teachers mentioned that there is still a lack of knowledge on how to best organize teamwork, along with mentioning that they lack an evidence-based curriculum for teamwork.

Disruption in Curricular Alignment and Prior Solutions

Based on the previously mentioned curriculum study, the questionnaire data, and the interviews with the teachers, a mismatch was identified between investing in CPS competencies as learning goals and the (limited) resources for the educational practice to meet these goals. Furthermore, we observed that teachers lack the insight and tools to assess the goal of fostering CPS competencies.

Solution analysis

In response to this and taking into account the expertise of the different partners involved in the project, we decided to design an interactive course of approximately half a day, in which students would learn the principles of CPS. Our ambition was that these principles could then be further transferred to other courses. In line with our curriculum analysis, we decided to focus more specifically on students from 10 to 14 years old. We also wanted to investigate how technology can help to teach, effectively support, and assess CPS in education in general, and particularly in the course that we designed to create a 'phygital' learning experience.

Last, our objective was to design a course where we could experiment with different storytelling techniques that were best suited for learning about CPS.

Persona	Target Group	Nationality	Date	Age	Gender	Type Onderwijs
SL doel - Digital High	Secundair (1ste graad)	Belgian	8 december 2020	30	Female	Kahtoliek Onderwijs
SL doel - Digital Medium	Secundair (1ste graad)	Belgian	9 december 2020	40	Female	Kahtoliek Onderwijs
SL middel - Digital High	Secundair (1ste graad)	Belgian	11 december 2020	40	Male	Kahtoliek Onderwijs
SL middel - Digital Low	Secundair (1ste graad)	Belgian	14 december 2020	51	Female	Kahtoliek Onderwijs
SL middel - Digital Me...	Secundair (1ste graad)	Belgian	21 december 2020	42	Female	Kahtoliek Onderwijs
SL middel - Digital Low	Secundair (1ste graad)	Belgian	23 december 2020	42	Female	Kahtoliek Onderwijs
SL doel - Digital Low	Secundair (1ste graad)	Belgian	23 december 2020	43	Female	Kahtoliek Onderwijs
SL doel - Digital High	Secundair (1ste graad)	Belgian	6 januari 2021	25	Female	Stedelijk onderwijs

FIGURE 2. Overview of the interviews.

For the curriculum design to be as effective as possible, we combined both the strengths of the partners involved in our project and the current literature on designing for CPS. Regarding CPS as a method, we found, for example, that combining activities on different social levels (i.e., individual, group, class) is more effective than using only one mode. Next, research indicated that teacher-led class interventions prove to lower feelings of competence frustration, especially for low-achievers. It is very challenging to know when an intervention on a certain level is needed as this highly depends on the progress of the different groups. However, technology can play an important role in improving that monitoring process. A second aspect of the design was to implement several tools to support this monitoring process. The knowledge about this aspect is mainly one of the strengths of the academic partners in the project (i.e., Augment and itec).

To keep the motivation and involvement of learners high, a third aspect we wanted to integrate was the use of interactive storytelling. We believe that a varied learning experience is more successful. So, learners can process information in different ways. Digital stories are "stories with a mixture of digital media, including text, pictures, recorded audio narration, music, and video" (Robin, 2016, p. 18). In line with the multimedia principle, the use of these kind of videos can be seen as beneficial. More specifically, this principle states that combining words and images is more effective than using words alone (Butcher, 2014). Furthermore, these kinds of videos can also positively affect students' motivation and involvement.

In conclusion, with our EDUbox Teamwork, we wanted to go beyond the current State of the Art by bringing together principles of computer-supported collaborative learning and digital and interactive storytelling.

SOLUTION DEVELOPMENT

In what follows, we focus on the second phase of our design-based research process (i.e., the design of the EDUbox teamwork) in which our goal was that students could learn about CPS by doing CPS. First, we give a short explanation of the 'EDUbox' format and how we develop it. Second, we focus on how we translated the concept of CPS to our use case, and we present the overarching (macro-level) blueprint of our course design. Third, we present the more detailed design of our course, which we refer to as the micro-level. Doing so, we mainly refer to the final design of our course and we indicate how this is in line with the preceding concept and needs analysis described previously. In the next section we will provide a more detailed overview of the iterative process which has led to the final design of some particular aspects presented hereunder.

Defining Our Approach to CPS

Introducing the EDUbox format

The EDUbox format is a learning experience that consists of slides, interspersed with videos and (digital) assignments. It takes learners through a linear experience, that consists of four acts. They use the EDUbox in groups of four to five students and the teacher acts as a coach. The EDUbox is graphically constructed using Adobe InDesign and then converted digitally. The different features are slides (i.e., tests, images, infographics), videos, a bot acting as moderator, a digital collaborative game, micro-lessons (e.g., quizzes), interactive repetition exercises, assessments (collection of data during the learning experience), and gamification elements (e.g., achievements).

We believe that a varied learning experience is more successful. We therefore try to apply knowledge in different ways (e.g., explaining a concept via an explainer video, a short digital test, and/or group reflection) so, they have to process the learning material in different ways, supported by both digital and physical materials.

Mapping CPS as a goal and CPS as a method

Our goal was to design the materials to learn about CPS (i.e., CPS as a learning goal) by doing CPS (i.e., CPS as a method). The first step in the design phase was to further define what CPS means and involves. As described earlier in the exploration phase, one of the guiding recourses therefore was the report of OECD (2017) in which a framework for CPS competencies is described. We decided to use this validated framework as a basis for the learning content within the EDUbox on teamwork. The following four dimensions are the main building blocks of the content of our course which were taught throughout the learning activities. The first dimension is called 'team with a plan'. Students are taught that during CPS activities, they need to (a) analyze the problem; (b) create a plan to solve the problem, ensuring that everyone agrees on it; and (c) be flexible by regularly making some changes to the original plan when needed (OECD, 2017). The second dimension is 'team with trust', this refers, among others, to the importance of communicating openly and treating each team member with respect (Graesser et al., 2018). The third dimension is 'team with different roles', accentuating the definition of different tasks during teamwork and the fact that everyone needs to know what to do during the task execution (OECD, 2017). The last dimension is 'team on the same page', referring to the importance of good communication and consulting each other regularly (Graesser et al., 2018).

Second, when designing the CPS as a method, we also took into account the prerequisites known in the literature to result in CPS and not just collaborative learning:

- **The goal:** a group has the goal of solving a novel and wicked problem by formulating a plan.
- **Monitor progress:** the quality of the solution can be evaluated during problem-solving and is visible to team members.
- **Differentiation of roles:** different roles are defined to achieve the goal and create individual accountability.
- **Interdependency:** CPS requires interdependency among team members. This means that each member is involved in the problem-solving process and has input.

Deciding upon the central theme and creating a macro-level blueprint of our design

The second step was to decide upon the leading storyline that is suitable for learning about CPS. After brainstorming with the different partners, we decided that space exploration would be a good theme since it is a topic that captures the imagination of many children and is considered one of mankind's greatest challenges. This theme is in line with the CPS prerequisites since it relates to many complex or wicked problems. We also defined the different characters of the story:

- **Protagonist:** the students themselves.
- **Antagonist:** the invisible conflicts inside the group and the space challenges.
- **Helper:** the Gandalf of our story is a coach in the form of videos and a virtual moderator.

The learning objective was clear, but to achieve this, we needed well-designed learning activities. Our third step was, therefore, to define the first blueprint of our course. This blueprint was based on the EDUbox format of VRT. This format consists of a recurring set of four acts (i.e., connect, concept, concrete, and conclusion). In the first act (i.e., connect) we introduce the general theme in line with the target audience's lifeworld and we make clear what the learning goals are. We also introduce the (metaphorical) antagonist and the conflict (i.e., ineffective teamwork) that needs to be overcome. In the second act (i.e., concept), students are introduced by the coach to new theoretical concepts and learn new skills. Step by step, they are prepared for the third act (i.e., concrete) in which students apply what they learned in the previous acts. They actively engage in teamwork and are presented with a challenge. In the third act, we build up towards a climax, a victorious moment. In the fourth act (i.e., conclusion), we therefore stimulate the students to transfer the newly acquired knowledge and skills to a final exercise. This overall storyline, including the structure of the acts, is also referred to as the macro-level script in the following text. We plotted these four acts on our general theme of space exploration, which resulted in four parts, (1) introduction, (2) training, (3) masterclass & Road to Mars, and (4) landing.

Summarized, in the introduction part, we determine whether the students are ready to go to Mars, by subjecting them to an initial test. In the second part, students are trained by the coach to become an effective team. This is a preparation for their mission to Mars. In the third part, students learn how they can apply the principles learned in the second part and they learn how to make the right decisions during the Road to Mars game, the group challenge. In the last part, the landing, students arrive on Mars and there is time to reflect and enjoy the journey they have completed.

The next step in our design process was to further refine this by integrating the right elements. In doing so, we tried to find the right balance between storytelling elements, appropriate learning activities on different social levels, and different media forms.

Development of the Different Parts on the Micro-Level

In what follows we explain the final micro-level design of each of the four parts in our course, which is the result of a long iterative process. Overall, the course is structured as follows. Part 1, the introduction, delves into both the challenges and advantages of collaborative efforts. As students progress, Part 2 unfolds, guiding them through structured training and introducing them to the four CPS dimensions.

FIGURE 3. Students building their imaginary rocket during the introduction game.

Through video content and a wide range of activities, they are systematically tested and encouraged to evolve into a cohesive dream team. Following this preparatory phase, in Part 3, students take on a leading role in a specially designed simulation game. This mission to Mars becomes the ultimate test, challenging participants to land on the planet (i.e., Part 4) with maximum energy.

Subsequently, some of these iterations will be discussed in the next section (see EVALUATION & REFLECTION LEADING TO ITERATIONS IN THE DESIGN PROCESS). It is important to mention that the order in which we present the different parts is not the chronological order in which these parts were designed. It is the order in which they are implemented in our course structure.

FIGURE 4. Explanation about why teamwork is important accompanied by a multiple-choice question.

FIGURE 5. Screenshot of a drag and drop exercise to discover some challenges in teamwork.

Part 1: Introduction

To activate our students from the beginning of the course, we started with a productive failure exercise. Specifically, the introduction starts with a group exercise in which students have to build a rocket as high as possible. In the design of this exercise, several task restrictions needed to be defined to foster CPS behavior. More specifically, certain limitations were defined. For example, students need to put an A4 sheet on the table on which they can build the rocket and the students are instructed that the 'imaginary' rocket (see Figure 3) can only be built with materials found in the class. Since students started using large objects, we decided, in a later part, that students could only use materials found in their backpacks out of safety considerations. Furthermore, to make the task more challenging, the activity was limited to three minutes including the collection of materials and building the rocket. It was required that the rocket could stand on its own.

Via this exercise, students are immediately introduced to some important aspects of teamwork and the course's theme of space. In combination with a group reflection on what went right and what could have gone better, the importance and the goal of this lesson are demonstrated.

The assignment and reflection are followed by a video on teamwork that highlights examples from their everyday life, such as working together to create TikTok videos. We also announce the ultimate challenge they will have to accomplish as a team at the end of the entire course, which is entitled the Road to Mars. The information about this challenge is however limited. We did this on purpose so that it could arouse students' curiosity.

The end of the introduction part is a kind of synthesis in which we integrated different learning materials and repeat the main ideas. We again let students discover why learning about teamwork is important, as research has found that less than 17 % of professional teams are effective (see Figure 4), we explain the benefits and challenges (see Figure 5. Screenshot of a drag and drop exercise to discover some challenges in teamwork.) of teamwork and provide opportunities for interaction to discover the benefits and challenges of teamwork.

Part 2: Training

During the training, the different CPS dimensions are consecutively explained to the students. In the design of this part, special attention was paid to the multimedia principle, stating that a combination of words and pictures is more effective than words alone.

FIGURE 6. Students watching a video with the coach.

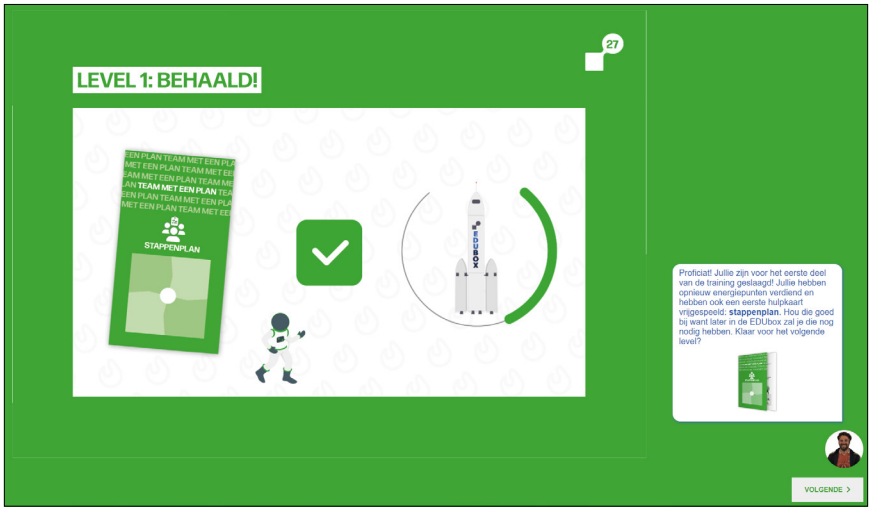

FIGURE 7. The virtual moderator announcing the completion of a level.

FIGURE 8. Students making a "living table".

As a technology-enhanced scaffold, the groups are guided by a coach as the central person in the instructional videos (see Figure 6) and in the form of a virtual moderator (see Figure 7) prompting during the learning activities. The advantages of virtual moderators, also referred to as pedagogical agents and virtual agents, can be numerous. In our case, the virtual moderator was integrated to guide students through the storyline and to motivate students; it guides the protagonist during their journey like Gandalf the wizard guides Frodo towards Mordor in The Lord of the Rings. For example, he announces that the students have completed one of the levels (i.e., a part of the training). This is visualized in Figure 7. In the section on the Iterations on the development of the virtual moderator and the Road to Mars, we elaborate on the development of our virtual moderator.

During the training, students are presented with various team tasks. Participants could, for example, discover the importance of trust, one of the CPS dimensions in our course, by making a "living table" (see Figure 8). Additionally, at the end of this training part, we integrated a situational judgment test (SJT), which students have to complete, together with their group, via an interactive video. This SJT was especially integrated to foster qualitative communication among group members. More specifically, in our SJT, students have to assess situations and indicate the most appropriate response to promote teamwork.

Part 3: Master class and Road to Mars challenge

The third part consists of two sub-parts: the masterclass and the Road to Mars challenge. Overall, in this part, students apply what they have learned in the training part.

In the masterclass, via a video, students get a briefing from the first Belgian Astronaut, providing a crash course on life in space. Based on this briefing and based on what students have learned during the training, they get to understand the

problem, define and assign roles in the team, and make group agreements. For this, several tactile tools (templates) are provided, that will assist them in doing so. After this, the preparation is done. Now it is time for our teams to go on their "Road to Mars" (see Figure 9).

The Road to Mars (game) is a group task in which we have integrated several game design elements. We more specifically developed a proxy of a complex problem, in line with the prerequisites of CPS, which we defined earlier (e.g., monitoring progress and differentiation of roles), but tailored to the age category of the students. The Road to Mars brings together the storyline (i.e., the theme of space exploration) and our learning objective (i.e., CPS) by completing a CPS task. The overall task consists of different problems students need to respond to via multiple-choice questions.

For example, the engineer gets to see the following problem on their device: "On space journeys, astronauts bring along a multitude of items. Some of you will be shown specific necessities that you must ensure to take to Mars. Identify the correct checklist." Subsequently, each team member receives an individual message outlining what they need to successfully complete the mission. For the pilot, for instance, the message reads: "To effectively carry out your duties as a pilot, it is imperative to have both fuel and a GPS."

Based on each team member's specific requirements, a joint decision must then be made from three comprehensive lists, each possibly containing or omitting the individual needs.

Based on their responses, the team score changes (see Figure 10). In the screencast (see https://youtu.be/2fdLFNSSBX8) a visualization is given of the Road to Mars. Further in this text, we elaborate on the different iterations based on the evaluations during the design process.

Part 4: Landing

After the final exercise (i.e., the Road to Mars), an application is integrated into

FIGURE 9. The translated version of the student CPS game interface on the shared screen.

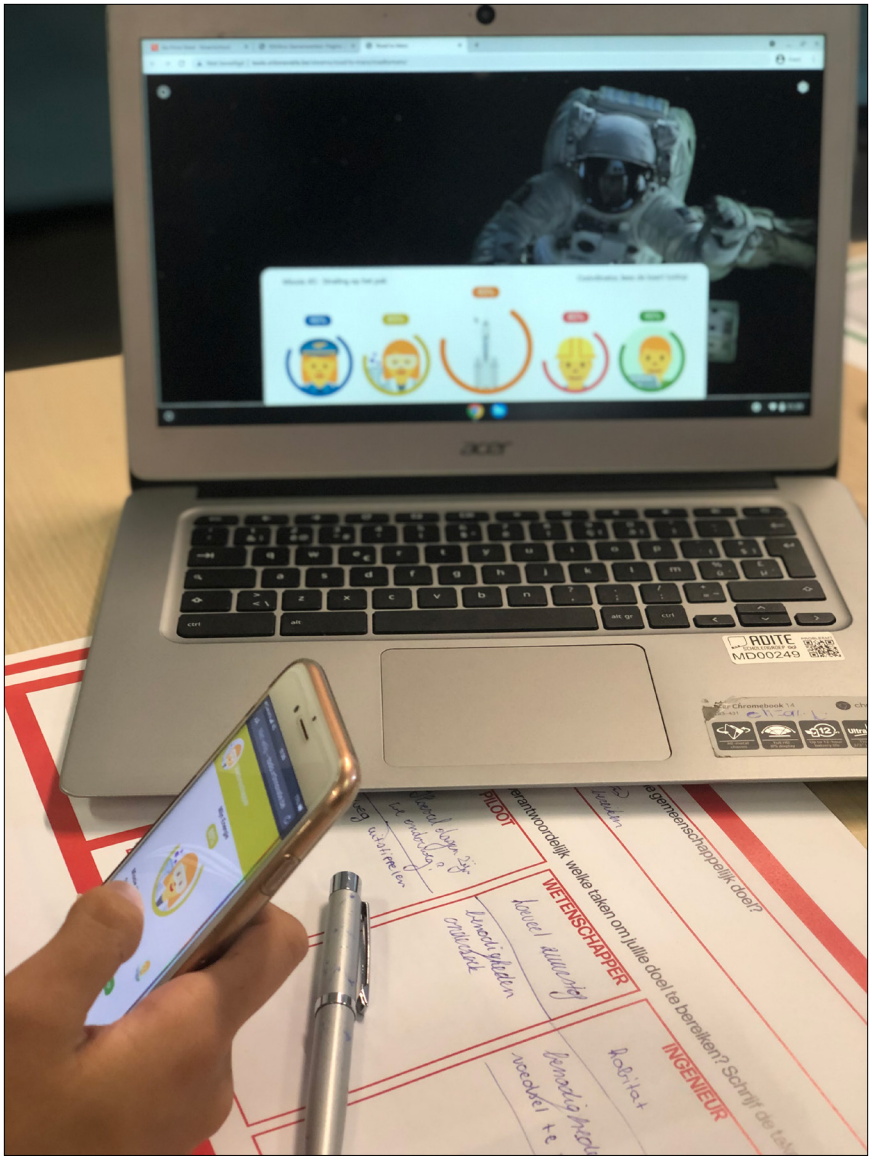

FIGURE 10. Students playing the Road to Mars game.

the platform through which students can take a team selfie which is then automatically integrated into a video showing the Mars lander landing on Mars (see https://youtu.be/zKTz84upJ5M). This video is a fun way to end the story and it also strengthens the team spirit. After this, students are invited to reflect on their team experience and performance during the exercise together with their teacher.

EVALUATION & REFLECTION LEADING TO ITERATIONS IN THE DESIGN PROCESS

Our final EDUbox Teamwork design is the result of an iterative process of evaluating and (re)designing. More specifically, the different proofs of concept have been extensively tested in the educational lab setting at the university campus in Kortrijk (see Figure 11), with around 90 students. In addition, we tested several parts at educational events with around 190 students of different ages and the complete EDUbox has been tested in different authentic classroom settings (see Figure 12) with around 140 students.

FIGURE 11. Students trying out the course in an educational lab setting at the university campus in Kortrijk.

In part of these settings, we asked students to fill out questionnaires and/or we observed students' interactions with the EDUbox content. These questionnaires, for example, consisted of open-ended questions on how students experienced the integration of the different videos that were integrated (i.e., storytelling elements). In other settings, we tested some of the technical elements, such as the Road to Mars and the virtual moderator.

Considering the numerous design failures we experienced and the iterations that we have gone through, describing all of them in detail would lead us too far here. In what follows we will therefore discuss a selection. More specifically, we will start by elaborating on how modifications were made in the integrations of digital stories through different phases. Next, we will elaborate on the design of the virtual moderator and the Road to Mars.

Modifications in the integration of digital storytelling

Many of the modifications that we made throughout the different iterations are linked to the way storytelling is integrated into our current EDUbox since we strongly believed in

FIGURE 12. Students trying out the course in an authentic class-setting.

the added value and the power of storytelling in educational practices throughout the design.

In our first versions of this EDUbox, storytelling was already used regularly and in multiple ways. For the students, the videos provided a good diversification regarding the learning materials. Many of the students reported via the questionnaires that, overall, "the videos were nice". However, as more videos passed, overall, students reported that they were less "curious about the continuation of the EDUbox" and through student observations, we noted students began to avert their gaze from the screen. Therefore, within the design team, we felt that we could bring the storytelling elements to the next level to foster the overall learning experience and we decided to start experimenting with the storytelling elements on two levels, the macro and micro levels, which are explained earlier in the section on defining our approach.

Shifting from a 3- to 4-act structure

At the macro level, we tested different storylines and tension arcs to engage the learner throughout the lesson. In traditional storytelling, one of the story structures that can often be found is what we refer to as the 'hero's journey': the hero-to-be lives a peaceful life until he is drawn into a conflict and is challenged with an important task, for which, in the end, he finds a good resolution. This kind of story structure thus consists of three major acts: the beginning, the middle, and the end. A learner's journey certainly bears similarities, but to keep a learner on track from the beginning until the end, adaptations were needed. In the current EDUbox, we have therefore evolved towards a four-act structure. Additionally, we also had to create a new type of tension arc that differs from the typical hero's journey. We will further elaborate on this.

Improving the introduction via active learning

While testing the prototype of our EDUbox, we noticed that the introduction of the lesson, one of the crucial parts, needed some modifications. In fact, in our first version, we started with a specific video to frame the theme. Our reasoning was as follows: we wanted to start the lesson with an exciting, arousing teaser, by using the right editing techniques and implementing the right music. This way, we could introduce the theme, create excitement, and involve the students by making a direct connection with their way of thinking. However, this was not yet appealing enough, in the sense that we did not get the full attention of our students. We realized that the initial introduction was rather elaborate and included a lot of text.

Therefore, when modifying this part, we decided to start the course with a physical activity in which the students would be activated. More specifically, in the final version, students need to build a rocket (see Figure 3). After testing out our new introduction part, we concluded that it was indeed more powerful than the previous version, increasing the fun-factor of the activity.

The introduction is a good example of the difference between our story arc and the typical hero's journey: we start with an important statement instead of quietly building up towards it in a conclusion. More specifically, our EDUbox starts with an exercise, then a teasing video, and then moves from personal reflection to class reflection. The way we have designed this is also in line with new narrative structures on social media, in which people start with the essence, because time is limited, and people want immediate attention. In short, from the start, we include various media and forms of learning in the sense that we jump from group, to class, to individual, and back to class.

Integrating videos in the most powerful way

Within this EDUbox, we distinguish three types of videos: teaser videos, reportages, and explainers. Teaser videos mainly have a motivational function. Explainer videos are the opposite and have mainly a retrieval value. The reportages include a combination of the motivational and retrieval values. For these types of videos, we involved experts by experience (a real astronaut, a weather forecaster, etc.) and we tried to find good examples that relate to young people's world. For an example, as seen in Figure 13, a screen capture of a reportage video in which Dirk Frimout, the first Belgian

FIGURE 13. Example of a reportage video with Dirk Frimout, the first Belgian astronaut in space.

astronaut in space was interviewed to share his experience of being a team member in space.

Integrating the right type of video at the right moment was a challenging task and doing so pretty much relied on our tests with the students (see Figure 11 bottom).

For the first part, we were pretty sure that a motivating video was needed. In the second part (i.e., the training), this was however more complex. The challenge here was to bring the rather theoretical content 'alive', because students expressed during the first trials that they "didn't do a lot" or that "it took too long". Therefore, we provided videos and quizzes that replaced some of the textual elements. Furthermore, the coach character was used in between the introduction of each of the CPS elements to connect the different parts. This was very useful, but we also had the feeling that it interrupted the flow of the learning experience. We therefore chose to make video reportages including concrete examples of how people in professional contexts deal with the different elements of teamwork (e.g., how does an architect work, how do media makers or game developers work together, etc.).

Another adjustment we made is related to how the video with Dirk Frimout, the Belgian Astronaut, was implemented. In the beginning, this video was implemented in the introduction part. However, since we also had to introduce the coach character in this part, it created some conflict in the design. Therefore, a new video was created based on the already existing content.

Searching for a protagonist and integrating the coach as a guide

An additional aspect of storytelling we experimented with concerns the different characters in the storyline.

Throughout our EDUbox, the learner is of course the protagonist, who will have to act to overcome certain problems. The problems are put in place by the antagonist, some kind of adversary. Sometimes, it is said that a good storyline can only be successful with a strong adversary. Finding this character, without losing the focus on our CPS theme, was not an easy task. More specifically, we wanted to set a clear goal, showing that cooperation is necessary, showing that it can be quite difficult, and making these difficulties concrete. However, after some discussion and brainstorming, we agreed that our antagonist did not have to be personified. Therefore, we decided to implement it rather as a metaphor. In our EDUbox we more specifically revealed that research shows that only 17% of teams are high-performing teams and 'the enemy' is often the elephant in the room. Based on this statement, students were asked to think about the reasons leading to unproductive teams. Answers to this question included frustration, a lack of involvement by certain team members and a lack of clear role division.

Next to the protagonist, someone to support or guide the students along the learning process, to overcome the problem, was also needed. We refer to this character as 'the Gandalf', as if it was a wizard who helps the student discover different solutions along the way. In our EDUbox, this person is called the coach, who gives the group the necessary tips and tricks. He is a funny, accessible, yet wise character who plays a major role throughout our videos.

Iterations on the development of the virtual moderator and the Road to Mars

Apart from the iterations we made regarding the integration of our storyline, different modifications have also been made to improve design failures of the ICT tools which are integrated into the EDUbox teamwork. In what follows, we will elaborate on two of them: the virtual moderator and the Road to Mars.

The virtual moderator as a coach

The first tool that we extensively tested and modified is the virtual moderator. At first, the virtual moderator was mainly implemented in our EDUbox to provide information in a

FIGURE 14. The first version of the virtual moderator.

FIGURE 15. Coach Tim, the new virtual moderator.

different way, so that not all the information provided to the students needed to be integrated into the slides in the learning environment. Furthermore, during CPS activities, the teacher cannot always be present to assist every group, and this way, the virtual moderator is a good way to assist both the teacher and the students.

The original virtual moderator, as shown in Figure 14, took the form of a chat interface appearing at certain times. We deliberately chose this form because young people use this kind of interface regularly in everyday life. Initial tests showed that students did find the amount of information provided via the virtual moderator easy to read and to the point. Via the virtual moderator, we also sent out informal, motivational messages. This among others included the foreshadowing technique, with which we send out an advance hint of what will come later in the course to keep students attentive.

Although the virtual moderator was very useful, the design of this feature did not yet fully fit into the broader theme of our course: training how to work as a team. Therefore, we came up with the idea of giving the function of virtual moderator to our coach character, who already had a supporting and guiding function in our concept. Our new virtual moderator, as visualized in Figure 15, was not a static image, as the previous one. It was designed so that based on the content of the message, the image of the coach changes, as visualized in Figure 16.

The Road to Mars

Our second tool which we have modified through several iterations is the Road to Mars. The creation of this game was one of the biggest challenges in the design process of our course. We needed to bring a story for different teams, integrating different CPS prerequisites (e.g., different roles). A story is often linear and has only one recipient. In this case, however, since there were multiple roles, we also had receivers and to foster interdependency, we needed to make the team members process different information from time to time. We thus had to integrate a form of multilinear storytelling.

To integrate the CPS prerequisite of role assignment and interdependency, we started the design of the game based on the concept of a card game in which participants draw a card on which a challenge/question is written with different answer options. The response needed to have an impact on the group's result, but we wanted everyone to be able to "land on Mars".

We first designed this game on paper (see Figure 17) to test out the game mechanics and to make further adjustments. Next, we converted this into an interactive game that students could play on a laptop. To facilitate conversations and effectively ensure that everyone on the team was involved, we made it possible to assign different roles to

FIGURE 16. Coach Tim's reaction when (top) you give a correct answer and (bottom) you click on him as a joke.

the participant per team. Therefore, team members need to scan one of the QR codes specifically linked to one of these roles (see Figure 9) with an individual device (e.g., smartphone or tablet). Per role, the content shown on the individual devices varies, which creates interdependency between team members, since team members need to communicate this information to each other to find the right solution. These individual devices are synchronized with the shared team device (e.g., laptop) on which the team's results are visualized (see Figure 10). The team's result represents the energy level of the rocket and the individual roles. More specifically, based on their answer per question, they lose a certain amount of energy: the more accurate the solution they choose, the less energy they lose.

During our first tryouts, we noticed that there was a need for the teams to be able to gain energy instead of losing it to foster the group spirit. We also noticed that an extra fun element needed to be integrated for variety. Therefore, a mini-game was added to the concept, in which students must navigate a rocket displayed on the shared screen, by using buttons on their individual devices.

CONCLUSION

Designing a fun and valuable learning experience for 10 to 14-years-old to improve CPS competencies was at the heart of this project. In this article, we wanted to share our design journey which was filled with both frustration - when students for example expressed being bored during the

FIGURE 17. The paper version and first prototype of our Road to Mars game.

training part and we realized that we had not reached our goal yet—and satisfaction - when observing students enthusiastically building the human table and when they were totally absorbed in the Road to Mars game. We realized that designing is about redesigning and iterating on different versions of the pieces of the puzzle, often balancing between evidence-inspired guidelines about the dimensions and prerequisites of CPS, and restrictions in educational practice. As we reflect on this design journey, we are also reminded of the Dutch proverb freely translated as "aim higher than your goal, for the arrow always descends in flight". Our ambition was high, driven by the integration of CPS as both a method and a goal, the adoption of a "phygital" format, and the incorporation of design elements like digital storytelling and various technological supports, including a virtual moderator seamlessly integrated into the entire concept. We realized that time is always too short and that we could have worked another two years on the refinement. However, projects come to an end, and we are proud that the results of the design process have been valorized through the EDUbox format on the VRT platform which is freely available and accessible to all students and teachers in Flanders. With the EDUbox Teamwork students are supported to acquire CPS skills which are becoming more and more important. Next, we hope that more and more students will be inspired in learning through digital storytelling as specifically, the incorporation of the Gandalf character, embodied in the role of the coach, plays a pivotal role in our narrative by offering support and guidance to students throughout this entire learning journey.

ACKNOWLEDGMENTS

This study was carried out within the imec. ICON research project STEAMS, with the financial support of imec and Flanders Innovation & Entrepreneurship.

REFERENCES

Butcher, K. R. (2014). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 174–205). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.010

Graesser, A. C., Fiore, S. M., Greiff, S., Andrews-Todd, J., Foltz, P. W., & Hesse, F. W. (2018). Advancing the science of collaborative problem solving. *Psychological Science in the Public Interest*, *19*(2), 59–92. https://doi.org/10.1177/1529100618808244

McKenney, S., & Reeves, T. (2012). *Conducting educational design research*. Routledge.

McKenney, S., & Reeves, T. C. (2014). Educational design research. In *Handbook of Research on Educational Communications and Technology* (pp. 131–140). Springer New York. https://doi.org/10.1007/978-1-4614-3185-5_11

OECD. (2017). PISA 2015 collaborative problem-solving framework. In *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving* (revised ed, pp. 131–188). OECD Publishing. https://doi.org/10.1787/9789264281820-8-en

Robin, B. R. (2016). The power of digital storytelling to support teaching and learning. *Digital Education Review*, *30*, 17–29.

Thijs, A., & van den Akker, J. (2019). Curriculum in development. In *Netherlands Institute for Curriculum Development*.

UNESCO. (2015). *Incheon declaration and framework for action for the implementation of sustainable development goal 4*. http://unesdoc.unesco.org/images/0024/002456/245656e.pdf

World Economic Forum. (2020). The future of jobs report 2020 | world economic forum. *The Future of Jobs Report*, *October*, 1163. https://www.weforum.org/reports/the-future-of-jobs-report-2020/digest