Deliverable Report

Extending Design Thinking with Emerging Digital Technologies

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(Integration of emerging new technologies into education and training)

Deliverable 7.1
Cycle 1 Evaluation Report

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1 Abbreviations

Abbreviation	Definition
DMP	Data Management Plan
DT	Design Thinking
ExtenDT²	Extending Design Thinking with Emerging Digital Technologies
LNU	Linnaeus University
NKUA	National and Kapodistrian University of Athens
NTNU	Norwegian University of Science and Technology
OU	Open University
PD	Professional Development
RRI	Responsible Research and Innovation
TCD	Trinity College Dublin
UGent	University of Ghent
VRobotics	Virtual Robotics

2 Summary

The ExtenDT^2 project aims to meaningfully enhance the pedagogic value of Design Thinking through the use of emerging technologies and in doing so, develop a concrete pedagogical approach which supports the digital transformation of education. In the context of ExtenDT^2, these emerging technologies include Artificial Intelligence, Authorable Learning Analytics, Augmented Reality, Virtual Robotics and 3D printing. The ultimate aim is to increase the uptake of such technologies in secondary education and develop young people's 21st Century Skills.

This report presents the evaluation of Year 1/Cycle 1, in which the existing project technologies are piloted in Design Thinking activities in classrooms and teachers engage in professional development activities. It concludes with recommendations for Year 2/Cycle 2 of the project, ranging from the initial and ongoing engagement of teachers, development of project technologies and activity plan template, through to professional development activities, the Year/Cycle 2 evaluation activities and ethical issues.

Appendixes A-H, which are available in a separate report, include the evaluation kit, case studies and professional development reports.

3 Introduction

3.1 Purpose and Objectives

Deliverable 7.1 presents an evaluation of the first year of the ExtenDT² project. The primary aim of this deliverable is to take an in-depth look at the implementation of co-design, school intervention and provisional development (PD) activities, with the purpose of informing the development of WPs 2, 3, 4, 5 & 6 in Cycle 2. The evaluation uses an exploratory case study approach, which allows the consortium to pilot and evaluate innovative pedagogic practice, professional development and technologies with QUAL+quant data collection instruments developed by the project team to meet the needs of each WP and local contexts.

At the commencement of Task 7.1, the primary aim was to establish a shared vision for the evaluation across the consortium through collaborative meetings and shared documents, through which the project aims and requirements of the evaluation from the perspective of each WP were identified. TCD then developed an evaluation toolkit for use in co-design activities (WP3), school interventions (WP5) and professional development activities (WP6) in collaboration with those WP leads. The draft evaluation plan was shared with all partners for feedback, followed by revisions and the construction of the evaluation instruments which were also provided to all partners for review. The final toolkit includes data collection instruments and guides as well as data analysis and reporting templates, which was implemented during co-design, school intervention and PD activities (Task 7.6). Partners were responsible for conducting the evaluations in their own countries (Task 7.7), the reports of which are available as Appendixes. The findings and recommendations presented in this deliverable are the result of a cross-project analysis of the case study reports and quantitative data.

3.2 Connection to Other Project Activities

Deliverable 7.1 draws on data collected from the co-design activities (WP3), school interventions (WP5) and PD activities (WP6) carried out in Year 1/Cycle 1 of the project. It aims to inform the development of WPs 2, 3, 4, 5 & 6 in Year 2/Cycle 2. These developments should impact the outcomes of intervention, as per the Design-Based Research approach adopted across the ExtenDT² project.

3.3 Structure of the Document

This report commences with an overview of the data collection and analysis approach to the evaluation, presented in Section 4 – Methodology, which follows. Individual case study reports can be found in Appendixes B-H, while the results of the cross-project analysis are presented in Section 5 – Findings. Each of these sections is structured according to the project activities – co-design, school interventions and PD. Section 6 presents an update on the status of the literature review with some initial points of note. Finally, Section 7 presents a discussion of key points with reference to the literature presented in Deliverable 2.1 and makes a series of recommendations to be considered by the project consortium, before concluding with next steps and a statement on RRI.

4 Methodology

4.1 Evaluation Context

The evaluation of ExtenDT^2 focuses on the overarching objectives of the project: 1) to develop students' 21st Century skills through engagement with Design Thinking activities in the classroom; 2) to enhance Design Thinking through the use of digital technologies; 3) to enhance the project technologies using emerging technologies; and 4) through co-design, school interventions and professional development enable the mainstreaming of emerging technologies and Design Thinking in classrooms. To achieve these objectives, ExtenDT^2 employs a Design-Based Research approach, this evaluation focuses on the first year/Cycle 1 of the project which aims to explore existing practices and technologies, whilst also piloting interventions in new settings.

Given the dearth of research on the use of technology to support design thinking pedagogy, in Year 1/Cycle 1, the research follows an exploratory research approach applied across three strands of ExtenDT^2 action: co-designing learning activities, school interventions and PD. The aim of the evaluation is to inform developments within the respective work packages (WP3, 5 and 6) as well as the development of the project technologies (WP4), the evaluation approach to be taken in Years/Cycles 2 and 3 of the project and ultimately the ExtenDT^2 framework (WP2), as part of a design-based research cycle. Specifically, this deliverable aims to inform the co-design of digital education resources to be used by teachers (WP3), the design of the extended version of the project's technologies (WP4), the design of the Learning Analytics and Dashboard component design (WP4), the Design Thinking activity plan template (WP5), the development of PD activities (WP6), the refinement of the evaluation toolkit (WP7) and the development of the teachers' toolkit.

Implemented in 5 different countries (Belgium, Greece, Norway, Sweden and the UK) by project partners and teachers with varying experience of research, design thinking and the project technologies, required a pragmatic approach to the research design. Thus it was necessary to identify data collection approaches which could be applied systematically across multiple research sites in multiple countries by multiple research teams, whilst affording these teams the ability to be responsive and reflexive within their own contexts. To support this, a detailed research protocol was developed and agreed. It was also necessary to consider variations between countries on the types of data that could be collected, resulting in alternative data sources.

4.2 Evaluation Approach

The evaluation approach incorporates mixed-method, multiple exploratory case studies to explore the project activities in different contexts. Each implementation of an ExtenDT² school intervention or PD activity is considered a single case study. This provides an opportunity to analyse each implementation in sufficient depth to be able to identify examples of best practice, evidence of the process in which learners and teachers engage, evidence of learning and areas for development. The results of these case studies are then brought together to inform a multi-dimensional analysis of the action as a whole.

4.3 Data Collection

The evaluation takes a mixed-method research approach. Questionnaires are used as the primary medium to collect quantitative data, whilst qualitative data is collected through observations (video, screen recordings, audio and/or semi-structured written), one-to-one and small group interviews, teachers' reflections, documents (activity plan, teaching and activity materials) and artefacts of learning (games created, worksheets completed, PowerPoint presentation created, etc.). If we are to understand why a particular activity is successful, we need to understand the experience of multiple learners. To do this data is collected from a variety of sources and triangulated to increase validity. The collection of data occurs at several different points throughout each action, whether held over several days or on a single day. It is important that data collection is rigorous, and the process is detailed in the Evaluation Protocols (Appendix A).

The following sub-sections provide a brief overview of the data collection approaches, with full details and instruments available in Appendix A. The process from preparation to data collection during the implementations and the evaluation is illustrated in Figure 1.

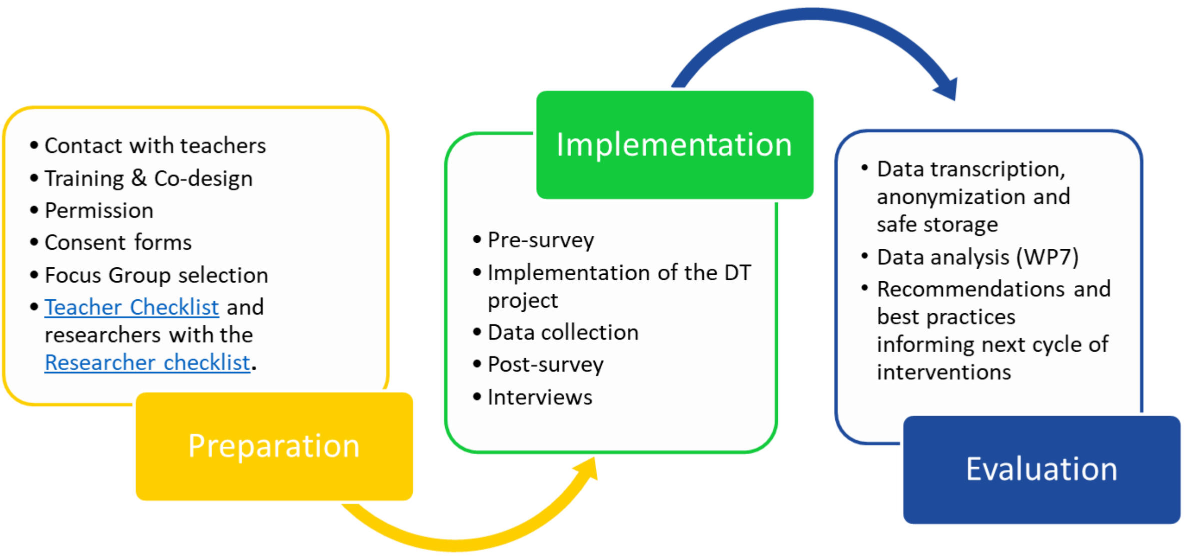

Figure 1 Three phases of evaluation in schools

4.3.1 Co-design

The process of co-design was based on online and face-to-face workshops between individual or group of teachers and researchers. The activity plan template was the tool used in all interactions and guiding discussions. This was completed by most teachers, with the exception of one who completed parts of it, and two who completed with help from researchers. The structure of workshops was communicated to all partners prior to interacting with teachers and was mainly used to inform the topics to be discussed in each workshop with the teachers. While the structure of interactions with teachers were guided by researchers, teachers were the ones making choices about how to use Design Thinking with their students, what technology to use and how.

The process of co-designing activities with teachers was captured through audio-recordings or hand-written notes by researchers. Specifically, at the OU, NKUA and LNU, workshops with teachers were audio-recorded following ethical approval. NTNU and UGent documented the process of co-design by taking notes during their interactions with teachers. The workshop guide created in WP3 included questions to prompt teachers in their thinking which would also provide valuable information for the evaluation.

4.3.2 School Interventions

School interventions were typically led by teachers in collaboration with researchers. In some cases the researchers led the classroom activities and the teachers observed/assisted. The main action occurs in the classroom, whether as part of the school day or after-school activities and involves students aged 11-18 years old. We anticipated each intervention to be different, based on different activity plans (see Deliverable 5.2), different teachers and different students, each within their own educational and social context. Therefore, the purpose of research at this phase is not to generalise but to understand what happens during Design Thinking activities which are facilitated by project technologies. For this research, each school intervention was treated as an exploratory case study, with data collection focusing on the action in **the classroom**, **the technology**, **the teacher** and **the students**. Within each case study, 2 groups of students who had all given informed consent/assent were chosen to act as "**focal groups**". Given the multiple layers of data collection, the words highlighted in bold above are used to organise the description of data collection below. Data collection tools are underlined.

The Classroom

Prior to the start of interventions photographs of the classroom/learning space WITHOUT students were recorded and/or a basic plan of the room created. These (together with annotations) may be used in the future where it is not practical or ethically appropriate to use video data or photographs of people.

In addition, researchers completed a case study context document, providing details about the activity plans, publicly available information about the school and non-identifying information about the class such as the number of students, length of lessons, size of groups, etc.

Where possible, a video camera would be positioned to capture the majority of the action in the room (including the teachers' desk, if appropriate). This provides an opportunity to capture the interactions in the wider room, such as whole-class teaching/instruction and student-teacher interactions. Where this is not possible, researchers use a semi-structured observation schedule to record the same.

The Technology

In Year 1/Cycle 1, most of the data relating to the technology came from interviews with students and teachers. However video (including screen recordings) and written observations of the **focal groups** may also provide some valuable insights into their interaction with the technology.

The Teacher

The teacher was asked to maintain a reflective diary to be completed after each session and before the next. It provided an opportunity to record design decisions, note issues that have occurred and recommendations for the future. These notes provided a guide for finding critical episodes.

After the intervention, teachers were invited to participate in one-to-one open interviews to discuss their experiences and share their views.

Activity plans and session materials were also collected to provide context for the action which occurs.

The Students

All students who had given their consent/assent to participate in the research, and had their parents consent to participate, were invited to complete a short survey at the start and end of the intervention, and could be invited to participate in a small group interview. Copies of digital artefacts (such as games) and other artefacts of learning, created by groups of students who have all provided informed consent, were collected.

Focal groups

In each class, 2 groups of students were invited to be the focus of more in-depth study, known as 'focal groups'. All participants in each group had to have given fully informed consent to participate in the study and have their involvement as part of a 'focal group' explained separately to them (consent to be a part of the focus group was already obtained via the general informed consent forms, but additional assent is important). Here the focus is on the interactions between students, between students and the teacher and between students and the technology.

Additional observations of the actions and interactions within these groups were captured via: Video recordings, with cameras positioned to capture the action of the group and/or cameras which students themselves use to record certain activities (e.g. brainstorming). Ideally the camera was positioned to capture the interactions between groups members AND the computer(s) they are working at. In cases where video recordings were not possible, these groups were the focus of additional semi-structured observations by the research team.

To supplement either video and/or observations, audio recordings were made of the group discussions. The audio recorders needed to be placed close to the students to pick up their voices over the general classroom noise. Additionally, where a video camera with sound recording is being used, it would typically be necessary to use an additional audio recording device in another position (e.g. if the video camera is behind the students and pointing generally towards a computer screen, it will be difficult to hear students that are facing the computer screen and therefore away from the camera. In this case it may be best to place the audio recorder directly below the computer screen).

Another form of observational data was collected through screen recordings of students' computers as they used the project technologies. This was used in the UK case where students all participated online as 'in the room' observations were not possible.

Each focal group participated in the small group interview mentioned above.

4.3.3 Professional Development

In Year 1/Cycle 1 the project aims to explore whether new, existing or adapted approaches used within partner institutions to teach pre/in-service teachers about Design Thinking and the project technologies are effective, and to explore students' experiences of those courses. While there is a substantial body of literature on teacher initial education and professional development, as a pilot of the professional development activities, an exploratory case study approach is still valuable. The two case study sites are UGent and NKUA teacher education courses which are described in detail in deliverable 6.1. As the availability/relevance of certain data sets are determined by the courses themselves, they are described in-turn below with reference to the courses.

UGent

Before the first workshop, students were informed about the study and given access to video materials that they should engage with in preparation for the first workshop. At the start of the first workshop, participants were then asked to complete a pre-course survey, focusing on demographic data, past experience and engagement with the online videos.

While the initial plan was to take photographs to document the layout of the room at different stages (e.g. direct instruction, group work, etc.) and moments of movement (e.g. a tutor working with different groups, or groups interacting with each other), this was not possible in practice. Instead, there was a greater reliance on semi-structured observations. These took both a holistic and a focused approach, recording the action in the room and focusing on the interactions within groups, their interactions with teachers and their interactions with technology. In total the action within 6 groups was recorded (2 groups per researcher).

At the end of each workshop, a reflective survey asked students about their experiences thus far. Those not participating in the research were to be reminded of the value of reflection and encouraged to reflect on the same questions but not to complete the survey. Following all workshops, students were invited to participate in open focus group interviews to discuss their experiences and share their views.

The facilitators maintained a reflective diary, completed after each workshop and before the next. It recorded workshop design decisions, noted issues that had occurred and recommendations for the future. In addition, all workshop planning and teaching materials were collected to provide context for the action which occurred.

Copies of games and other artefacts of learning, created by groups of students who have all provided informed consent, were also collected.

NKUA

At the start of the first workshop, participants were asked to complete the same pre-course survey as those at UGent. During each workshop, semi-structured observations enabled both a holistic and a focused approach to recording the action in the room, focusing on the interactions within groups, their interactions with teachers and their interactions with technology. At an interim point and the end of the workshop series, reflective surveys asked students about their experience thus far – using the same survey used by UGent.

Between workshops, students are expected to use a forum to discuss issues with their team and the course tutors. Where all students within a forum have signed informed consent documents, the forum posts were collected.

As in UGent, following the completion of the workshops, students were invited to participate in open focus group interviews to discuss their experiences and share their views. The facilitators also maintained a reflective diary and all workshop planning and teaching materials were collected to provide context for the action which occurred. Again, copies of digital artefacts (such as games) and other artefacts of learning, created by groups of students who had all provided informed consent, were collected.

4.4 Ethics

Those partners involved in each action (LNU, NTNU, OU, NKUA and UGent) were required to gain ethical approval at the statutory level within their own countries. For example, within NKUA, UGent and the OU, institutional approval was required, while at LNU and NTNU national approval had to be obtained. In the case of LNU, this process (rather than the outcome of the process) prohibited participation in Year 1/Cycle 1, a point returned to in the Discussion section of this deliverable. Additionally, while TCD was not involved in data collection, they were to be involved in data analysis and therefore appropriate ethical approval was obtained.

The independent ethics expert on the EAB reviewed all data collection and analysis plans, noting that the research design followed standard approaches in the social sciences and that due consideration had been given to the approaches to gaining informed consent from parents and assent from children (see Deliverable 9.1)

Following ethical approval, partners involved in school interventions needed to arrange access to schools and in some cases, schools limited the forms of data that could be collected – for example, in the case of NTNU video data could not be collected. Schools then supported partners in the process of gaining informed consent from parents and informed assent from students who would participate in the activities.

4.5 Data Analysis

4.5.1 Co-design

Deliverable 3.1 provides a narrative account of the co-design process followed by each partner through analysis of researcher notes and session recordings. These accounts enabled the WP3 team to identify areas of the co-design process that were effective and ineffective in different contexts.

4.5.2 In-depth Case Studies

Both school interventions and PD case studies were analysed individually by local partners. Taking a QUAL+quant approach, data analysis began by reviewing all contextual information, including the activity plans and resources. Qualitative data (QUAL) was the primary data collection approach with an interpretivist approach to data analysis. Quantitative (quant) was a secondary approach. There were four phases to the data analysis. The first was constant comparative analysis, an inductive approach used to identify issues most pertinent to participants which drew on data from interviews and reflections of students and their teachers as the primary data sources and used observational data as secondary sources. Critical incidents were then used to identify events that were significant in the action and to explore them in depth using observational data (video, audio or written) primarily with interviews and reflections providing supporting or refuting evidence. The survey was analysed using descriptive statistics. As the survey was not designed to be a pre-post test and acknowledging that each context it was administered in would be significantly different, there was no intention to use these findings beyond providing additional context and evidence to the constant comparative analysis and critical incident findings. Finally, using the activity plan to structure the analysis, evidence of students' learning was explored in each case study using the previous analyses and artefacts of learning.

4.5.3 Cross-project Analysis

Once all in-depth case studies for the school interventions were complete, a cross-project analysis of the action was conducted by the evaluation lead, TCD. The codes and categories generated and reported in each case study was used as an initial coding template to analyse the case study results. The aim was to find supporting and refuting evidence across the school interventions, whilst being cognisant of contextual differences which may account for the similarities and differences. Additional codes were generated through analysis of the critical incidents, descriptive statistics and evidence of learning analyses. An additional analysis of all survey data from school students was also conducted to explore emerging trends across the project, with t-tests utilised to test for statistically significant differences between male and female students. While there was a third category for gender, insufficient students selected this option to run statistical tests. Additionally, while gender and location are anticipated to be important factors, there was insufficient data to explore this. A similar approach was taken for the PD case studies. The findings from the cross-project analyses are presented in the following section, with reference to the relevant individual case studies.

5 Findings

The findings are organised according to the actions they relate to: co-design, school interventions and PD. In the case of school interventions and professional development activities, the results of each in-depth case study are reported in Appendixes B-H. What is presented here are the results of the cross-project analyses which integrate and reference these individual case studies under the core project themes of Design Thinking, Technology and 21st Century Skills

5.1 Co-design

Lessons learned from the process of co-designing activities with teachers, reported in Deliverable 3.1, include:

a. Three one-to-one sessions (1 hour each) can be an effective approach for introducing teachers to technologies and Design Thinking and supporting them in completing activity plans. A key component of these sessions is researchers scaffolding a process of reflection with teachers that can provide insights as to what teachers understand, or need help with, regarding Design Thinking and technologies, as well as justify choices teachers make regarding aspects of the activity template. At NKUA it proved necessary to provide teachers with a virtual space to participate in the co-design in their own time to ensure participation.

b. One additional session (or a series of email exchanges) with teachers is required to discuss the overall implementation of activities with students including processes of data collection, role of researchers and allocation of consent forms.
c. A misunderstanding observed with some teachers was a heavy focus on using technologies with students and less emphasis on Design Thinking processes. It should be made clear to teachers that the starting point of Design Thinking projects is a problem or a need that students are asked to explore and solve; technologies should be seen as tools to support Design Thinking process instead of the main focus of activity. Also, teachers should seek to identify an alignment between Design Thinking projects and learning objectives, so Design Thinking serves existing learning goals.
d. Making Design Thinking and technology resources available to teachers before the start of workshops can give teachers time to engage with them enabling them to be better prepared when joining the workshops.
e. It may be useful if students experiment with technologies in the classroom before the start of Design Thinking sessions; this was an approach trialled by one of the OU teachers. The teacher decided on which technology to use following students' engagement with technologies. Also, students developed a basic understanding of how to use technologies that helped with the Design Thinking implementation.
f. Design Thinking and its stages should be clearly explained and communicated to students before they start designing activities for each stage, to enable learning about Design Thinking.
g. Project technologies should work without bugs and be challenging enough for students. For example, easier technologies such as SorBET were positively endorsed by teachers working with younger students.
h. Participating teachers had expertise in different disciplines; in the UK, a teacher with a computer science background dropped out from the project when he realised that the focus of Design Thinking projects was to solve a problem; he perceived the approach as being more suitable for other subject areas such as humanities and social sciences. In contrast, in Belgium, computer science teachers were those most interested in taking part in the project. It was a challenge to recruit teachers teaching other subjects. Such discrepancies may be explained by how the project was presented to teachers (by the researchers) and what emphasis was placed on technology use versus Design Thinking as a means to solve a problem. There may be a need to provide teachers with examples of Design Thinking projects to highlight the potential of Design Thinking across disciplines.

5.2 School Interventions

School interventions designed following the activity plan template (WP5) and using the project technologies (WP4), were planned in schools in Belgium, Greece, Norway, Sweden and the UK. However, issues with gaining ethical approval and data collection meant that the evaluation had to be based on the activities from Greece, Norway and the UK, involving a total of five interventions. Reports presenting each case study, including an overview of the data collection and in-depth analysis, are presented in Appendixes B-F. This section presents the results of the cross-project analysis.

5.2.1 Design Thinking

Time

Insufficient time was a recurring issue across all five of the case studies. In Greece, both students and teachers were negative about the potential use of Design Thinking in education largely due to the time constraints. They noted that in a formal school context Design Thinking would require significant time commitments, making it difficult to integrate into the existing schedule unless the process is streamlined and well prepared. Significantly, the interventions in Greece were the longest, totalling 8 hours each, by comparison to 5 and 6 hours in the UK and Norway.

For students there was a sense of frustration that they did not have time to put all of their ideas into their final solution and that they did not have time to act on the feedback of their peers. This issue is one which is both relevant to the design of the school interventions (the time available, managing expectations, project scope, etc.) and the development of time management skills which is picked up again under the section on 21st Century Skills. In two of the three cases, the Discovery phase took longer than planned which meant that subsequent phases had to be merged, shortened or removed as was the case of the Deliver phase in the VRobotics case. Yet, students themselves felt rushed in the Discovery phase, which may be related to technology issues and unfamiliarity with a new tool but also may be an indication of their engagement with the chosen topics.

In the UK, where the Design Thinking activity was completed in the shortest time (5 hours across 5 lessons), the teacher felt under pressure to complete all phases and the conclusion drawn in the report is that the teacher may have skipped parts and some students may not have understood all aspects of the sessions. By comparison in Norway, a dedicated project day was needed due to the interdisciplinary nature of the project and teacher concerns over how to fit Design Thinking into the curriculum.

Suggestions to address the issue of time include utilising homework time and the use of a flipped classroom model, to simplify the Design Thinking process.

Personally Meaningful & Active Engagement

Throughout the phases of Design Thinking, there was evidence that students valued the activities because they were personally meaningful and required active engagement throughout. Through the Discover and Define phases, students felt engaged as they created a personally meaningful connection to their project which was a significant motivating factor for some. Teachers also described this as generating “buy-in” from students into the activity. Having a shared sense of ownership within their teams and a clear sense of purpose encouraged students to engage and that engagement was characterised as active throughout but most notably in the Discover, Define and Design phases. Empathising was also described by one as stimulating creativity.

Discover

The Discover phase was particularly identified as a time when students learned a lot through research and being tasked to empathise with an end user. This could be through formal sources such as a study on the nQuire platform, websites, books or videos or informally by sharing experiences and ideas with each other. However, it was often the most time consuming and students felt that they needed more time in this phase and in some cases the teacher extended the time which caused other phases to be restricted in terms of time.

Define

There were no notable references to the Define phase, although one student did note that it was challenging to translate their abstract project ideas into concrete designs using the project technologies.

Design

The Design phase provided opportunities for students with different knowledge and skills to contribute to the shared solution. It provided opportunities for creative expression and creative thinking both in terms of solving problems but also when thinking about the user experience. For some it provided an opportunity to practice and enhance their programming and coding skills, with one student noting that it greatly increased their confidence. Many identified it as both the most interesting and most challenging phase of the project.

Deliver

Students valued the opportunity to share their solutions with their peers. For some it was a particularly important part of the process: “*“We collaborated by making something special and assuming that someone would see it and judge it afterwards, just like we do with other games.”* Yet in one case, due to time constraints, it was cut from the activity. It provided an opportunity for them to learn from one another, although some technical difficulties presented barriers when students wanted to play each other’s games.

While the Deliver phase provided a more formal opportunity for students to present their solutions, they found it an equally valuable opportunity to gain feedback. Yet not all feedback was meaningful and students noted that their peers may benefit from guidance on how to critique and give feedback to others and also how to respond to feedback. Equally, within the

Design Thinking projects, many students did not have an opportunity to act on the feedback they had received.

5.2.2 Technology

Time

Time was also raised as an issue in relation to the project technologies. In Greece it was noted that both teachers and their students needed more time than anticipated to learn how to use specific tools and applications. One approach suggested to address this is time outside the classroom for students to engage in familiarisation tasks, alternatively students may be grouped based on their digital skills and existing familiarity with a tool. Students also noted that they needed more time to code with ChoiCo to achieve their ambitions and improve on their games. However, it is unclear whether this is related to time management, the pre-existing skills of the students or the technology itself.

Rapid Prototyping

The tools were recognised by students and teachers as highly valuable for the rapid prototyping of solutions. They enabled students to quickly trial ideas, identify problems and test solutions. Significantly, one teacher noted that the tools "*effectively supports such processes by providing feedback to users, enabling continuous experimentation without the fear of making mistakes*.''

ChoiCo

ChoiCo was used in each country. Students found it easy to use but felt that it had limited functionality, in particular for sharing the games they created with other students. In one case, students noted that this limited collaboration, meaning that larger groups of four students split into smaller groups. It was also noted in each country that students encountered technical problems, or bugs, when using the software. While one teacher of Computer Science was able to turn this into a 'teachable moment', in other contexts students were left feeling frustrated. Students noted that they would have valued tutorials and instructions for using ChoiCo, which might have gone some way to alleviating this frustration.

MaLT2

MaLT2 was only used in one case study and by a teacher and students who were already familiar with it. While there were no particular challenges or advantages reported, one student with no previous experience did note finding some difficulty working on a three-dimensional design.

nQuire

In the NKUA 011 case, students used nQuire in the Discovery phase. It was noted by the teacher that a significant amount of time was lost during this phase due to students being unfamiliar with the tool and due to the range of functionality. They also noted that the need to use codes/credentials to access the platform also caused delays due to students forgetting their codes and that "*this measure hinders the effortless dissemination and fulfilment of surveys that could potentially be produced by students through external* [tools].'' The implication of this was that subsequent Design Thinking phases had to be truncated. Students also reported finding the tool complicated: "*It was somewhat complicated to create missions in the nQuire platform, and we couldn't understand if we had uploaded the mission successfully."* This was a finding echoed in the survey data from NTNU and the OU.

SorBET

There was limited evidence regarding students' use of SorBET, however one point that was noted was the need for more instructions or scaffolds when creating the games.

Virtual Robotics

Virtual robotics were used in the NTNU case study referred to as VRobotics. Students generally found the tool easy to use and engaging, but some noted that steering the robot was difficult. There was no mention of time constraints with reference to the virtual robotics programme. This may be due to the design of the activity or in equal part to the technology and the digital skills of the students.

5.2.3 21st Century Skills

Students referred to engaging with and developing a number of 21st Century Skills, including teamwork, collaboration, cooperation, communication, creativity, critical thinking, reflective thinking, problem solving, perspective taking, digital skills, task and time management, flexibility and research skills. This section discusses those which were most prominent across the reported school interventions.

Time Management

While the time available within a traditional school timetable was viewed as a significant constraint, students also reflected on their own ability to effectively use their time to meet their planned objectives. As one student from NKUA 011 case study states, "*if time were more properly managed and we finished the Project, it would be one of the most fun!*" While in the NKUA 012 case study the teacher recognised this and actively tried to develop their students time management but without using any specific tools or scaffolds.

It was also noted in the NTNU 01 case study that students had ideas that were too ambitious for the time available, while students in the VRobotics case study felt that the timings of the session were good except when it came to the prototyping phase which took longer than expected, and ultimately meant that the Deliver phase was left out. It is worth noting that in these cases, students in the pre-survey had a strong sense of self-efficacy when it came to 'managing myself' but were less confident when it came to 'working with others'. It is possible that both a false sense of their ability to manage their own work and a lack of confidence or experience in working with others contributed to time management problems. In the post-intervention survey, only one student identified 'task management' as a learning opportunity.

Teamwork

This sub-heading captures several aspects of teamwork, including collaboration, cooperation and team structures and organisation. In terms of collaboration, students and teachers identified multiple ways in which they collaborated, including collaborative tasking, cooperative tasking and individual tasking depending on the activities they were involved in. In the pre-survey, students were less confident in their own skills when it came to 'working with others' than communication, creativity and using technology. Students described working as part of a team as fun and preferable to working on their own. They cited having learned because they were part of a team in which each member complemented the knowledge of others and in one case described collaboration as a way to ensure justice and equality of all students in the group by committing to do an equal share of the work and support each other. They valued sharing their ideas, although communication and coming to a consensus was a challenge in some groups.

The only significant challenge that was noted in terms of the size of groups was when it came to the tasks that students needed to do. In Norway, it was noted by students that ChoiCo limited their ability to collaborate due to the lack of sharing functionality. But more generally, they noted that in groups of four, some people disengaged as there was nothing for them to do and there were lost opportunities for learning.

Both students and the teacher in NKUA 012 case study noted that they had participated in group projects before but that the students had simply divided up the work and not collaborated. With Design Thinking they had a common goal and shared the final product which fostered collaborative working.

Communication

Communication was the second most referred to skill after collaboration and cooperation. This is understandable given that communication skills are essential for effective collaboration and cooperation, yet it was noted by both teachers and students that it was an area for development. Students were most likely to become frustrated when they felt that their voices were not heard.

In NKUA 012 case study it was noted that 'communication' was initially not included as a learning objective under 21st Century Skills, but was perhaps the most challenging aspect for students. It was also a skill that students across case studies noted that they used and developed, particularly listening to other people. It was essential for students to make decisions about the construction of their games, but also difficulties emerged during the process when students felt they were not listened to, or consensus could not be reached. From the report it is clear that in some cases, students came up with their own ways to build consensus but would have benefitted from guidance from the teacher early on.

Throughout the activities, students recognised the importance of listening to the views of others, as well as having their own ideas listened to. Additionally written communication and visual presentation skills were recognised as valuable for communication by groups who created an artefact such as a poster to present their solution to others. Teachers also noted the valuable opportunities afforded by the Design Thinking approach for students to develop their ability to consider the perspectives of others in their communication "*I think a skill that would that my kids are still learning to develop is the ability to recognise it, and it's that perspective-taking again, it's being able to know that just because they drew a picture and they know what they mean by it doesn't mean that it's being communicated clearly to others and being able to communicate what their ideas are. So that other people can understand what their ideas are.*"

Reflection

Several students across cases noted that collaborating in a team and the digital tools they used, encouraged and enabled them to engage in critical reflection on both their actions and their learning. Reflection is something that is not explicitly referred to in the activity plans and may be a valuable tool to raise students' awareness of what they are learning, how they are learning and areas they personally need to develop.

Digital Skills

The majority of students referenced using and developing their digital skills, with programming skills being the main outcome of the Design Thinking activities for some. They found programming the virtual robotics and games fun and rewarding as they were quickly able to see the implications of their code, gaining feedback which informed their next steps.

5.2.4 Student Survey Results

Student Pre-survey

173 responses from 3 student groups in Norway, 3 groups in Greece and one group in the UK. The medium length of time it took students to complete the survey was 3 minutes and on average it took less than 5 minutes. So far the school interventions have been aimed at the lower-end of secondary school. Children's ages ranged from 11 to 14, with the majority (96 out of 172 respondents) aged 13.

There was a relatively even split between genders across the interventions, with 52% of students identifying as male, 45.7% of students identifying as female and 2.3% selecting 'other/prefer not to say'. The ratio of participants is as expected, given that school interventions took place as part of the normal school day, so all children had to participate.

In Greece, all students were native speakers of Greek, while in Norway and the UK there were students for whom the language of the survey or language of instruction was an additional language.

The only statistically significant differences between genders were in students' responses to questions about technology.

21st Century Skills

The SICKS instrument (Bray et al, 2020) provides a measure of students' self-reported confidence in 21st Century Skills. Overall, students were more confident using technology for educational purposes and managing themselves than communicating, critical thinking and working with others (see Table 1). This was largely predictive of the results in the post-survey, except for students' ability to manage themselves.

Table 1 SICKS averages by item and gender

		Gender: I am ...			
		Male	Female	Other/Pre	Total
Working with others: Working with others - collaboration	Average (Work in pairs or small groups to complete a task together)	4.3	4.3	3.5	4.3
	Average (Work with other students to set goals and create a plan for your team)	3.6	3.7	3.8	3.7
	Average (Create joint products using contributions from each student)	3.6	3.5	3.0	3.5
	Total	3.8336	3.8248	3.4166667	3.82
Communicating: Communicating	Average (Communicate your ideas using media other than a written paper)	3.8	4.0	4.3	3.9
	Average (Prepare and deliver an oral presentation to the teacher and others)	3.8	3.6	3.0	3.7
	Average (Answer questions in front of an audience)	3.5	3.2	2.8	3.3
	Total	3.69326	3.5654	3.3333333	3.62
Creative: Being creative	Average (Test out different ideas and work to improve them)	4.1	4.1	3.5	4.1
	Average (Invent a solution to difficult problems)	4.0	3.8	4.8	3.9
	Average (Create something new that can help you express your ideas)	3.7	3.8	4.5	3.8
	Total	3.95402	3.8889	4.25	3.93
Myself: Managing myself	Average (Track your own progress and change things if you are not working the way that you should be to complete a task)	4.0	4.0	4.3	4.0
	Average (Assess the quality of your work before it is completed)	4.1	4.1	4.0	4.1
	Average (Use peer, teacher or expert feedback to change your work)	4.0	4.1	3.3	4.0
	Total	4.01859	4.0818	3.8333333	4.04
CT: Managing information and thinking	Average (Try to solve problems or answer questions that have no single correct solution or answer)	3.8	3.5	4.3	3.7
	Average (Draw your own ideas based on analysis of numbers, facts or relevant information)	3.7	3.4	4.8	3.6
	Average (Analyse different arguments, perspectives or solutions to a problem)	3.7	3.7	4.3	3.7
	Total	3.73051	3.5007	4.4166667	3.64
Tech: Using technology for educational purposes	Average (Use technology to work in a team)	4.5	4.2	3.5	4.4
	Average (Use technology to keep track of your work on assignments)	4.0	3.8	3.3	3.9
	Average (Use technology to help to share information)	4.0	3.9	3.3	3.9
	Total	4.17045	3.987	3.3333333	4.07

Technology Use

The majority of students use desktop computers or laptops regularly which important given that the project technologies are browser based. The only notable difference in the use of technology between genders is in games console use which is male dominated (see Figure 2). But when it came to their confidence in using technology, there was a statistically significant difference ($p<0.05$) between genders (Figure 3).

Gender:		Device use:		%
Male	(90)	Desktop computer/laptop	78 of 90	86.7%
Female	(79)	Desktop computer/laptop	66 of 79	83.5%
Other/Prefer not to...	(4)	Desktop computer/laptop	3 of 4	75.0%
Male	(90)	Games console	60 of 90	66.7%
Female	(79)	Games console	23 of 79	29.1%
Other/Prefer not to...	(4)	Games console	1 of 4	25.0%
Male	(90)	Smart home device	21 of 90	23.3%
Female	(79)	Smart home device	16 of 79	20.3%
Other/Prefer not to...	(4)	Smart home device	0 of 4	0.0%
Male	(90)	Smartphone	83 of 90	92.2%
Female	(79)	Smartphone	73 of 79	92.4%
Other/Prefer not to...	(4)	Smartphone	4 of 4	100.0%
Male	(90)	Tablet	38 of 90	42.2%
Female	(79)	Tablet	32 of 79	40.5%
Other/Prefer not to...	(4)	Tablet	1 of 4	25.0%

Figure 2 Technology use by gender

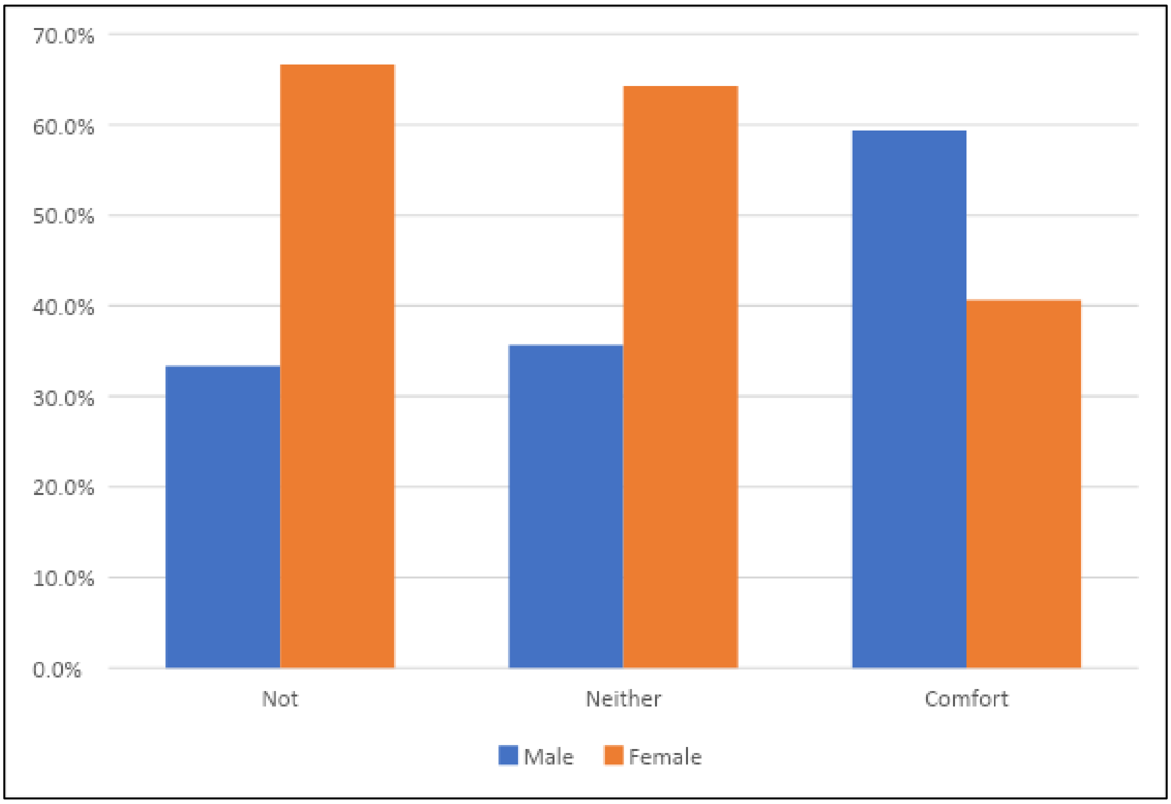

Figure 3 Responses by gender to the question 'How comfortable are you with using technology?'

Very few students use technology to create digital art or graphics, create videos or play games (Figure 4). Students tend to consume rather t5han produce digital media. Female students are more likely than their male counterparts to report collaborating with others on digital projects or presentations.

Gender:		Tech		%
Male	(88)	Collaborating with others on...	41 of 88	46.6%
Female	(79)	Collaborating with others on...	52 of 79	65.8%
Other/Prefer not to...	(4)	Collaborating with others on di...	1 of 4	25.0%
Male	(88)	Creating digital art or graphics	17 of 88	19.3%
Female	(79)	Creating digital art or graphics	19 of 79	24.1%
Other/Prefer not to...	(4)	Creating digital art or graphics	0 of 4	0.0%
Male	(88)	Creating digital videos	17 of 88	19.3%
Female	(79)	Creating digital videos	22 of 79	27.8%
Other/Prefer not to...	(4)	Creating digital videos	1 of 4	25.0%
Male	(88)	Online research and reading	65 of 88	73.9%
Female	(79)	Online research and reading	64 of 79	81.0%
Other/Prefer not to...	(4)	Online research and reading	2 of 4	50.0%
Male	(88)	Playing educational games ...	38 of 88	43.2%
Female	(79)	Playing educational games ...	32 of 79	40.5%
Other/Prefer not to...	(4)	Playing educational games or ...	3 of 4	75.0%
Male	(88)	Watching video tutorials or ...	63 of 88	71.6%
Female	(79)	Watching video tutorials or ...	49 of 79	62.0%
Other/Prefer not to...	(4)	Watching video tutorials or wal...	2 of 4	50.0%

0.0% 20.0% 40.0% 60.0% 80.0% 100.0%

Figure 4 Use of technology by gender

Most students had familiarity with Microsoft and/or Google Suits and more than 75% used social media (Figure 5). However less than 50% had experience with programming tools, video editing software or Adobe.

Gender:		App use:		%
Male	(89)	Adobe Creative Suite (Photos...	16 of 89	18.0%
Female	(78)	Adobe Creative Suite (Photos...	14 of 78	17.9%
Other/Prefer not to ...	(4)	Adobe Creative Suite (Photosh...	0 of 4	0.0%
Male	(89)	Microsoft/Google Suits (Word...	82 of 89	92.1%
Female	(78)	Microsoft/Google Suits (Word...	72 of 78	92.3%
Other/Prefer not to ...	(4)	Microsoft/Google Suits (Word/G...	3 of 4	75.0%
Male	(89)	Programming tools (Scratch, ...	40 of 89	44.9%
Female	(78)	Programming tools (Scratch, ...	27 of 78	34.6%
Other/Prefer not to ...	(4)	Programming tools (Scratch, Py...	1 of 4	25.0%
Male	(89)	Social media platforms (Insta...	74 of 89	83.1%
Female	(78)	Social media platforms (Insta...	63 of 78	80.8%
Other/Prefer not to ...	(4)	Social media platforms (Instagr...	2 of 4	50.0%
Male	(89)	Video editing software (iMovi...	25 of 89	28.1%
Female	(78)	Video editing software (iMovi...	24 of 78	30.8%
Other/Prefer not to ...	(4)	Video editing software (iMovie, ...	1 of 4	25.0%

0.0% 20.0% 40.0% 60.0% 80.0% 100.0%

Figure 5 Software use by gender

Student Post-survey

In total 152 eligible responses were recorded in the post-survey from 3 student groups in Norway, 3 groups in Greece and one group in the UK. This reduction in participants was due to ethical issues discussed in the limitations section and resulted in a decreased percentage of female students. 56.3% of respondents were male, 40.4% were female and 3.3% chose ‘other/prefer not to say’. The median survey response time was 16.5 minutes and the average was less than 18 minutes.

Design Thinking Process

The survey aims to find out the extent to which students had participated in various elements of Design Thinking activities. Overall, students tended to agree that they had participated in the various elements of. The strongest results were that 90.8% of participants agreed that they had ‘helped make decisions about what our group would create’, with an average of 4.33 (where 5 is strongly agree and 1 is strongly disagree) and median response of 4. 84% of participants agreed that they had ‘tested and improved the solution’ with an average of 4.23 and median 4. However, less than half agreed that they had ‘found out about the needs of other people’ (42.6%), with most (43.3%) choosing ‘neither agree nor disagree’ for this statement. Equally, students tended not to agree with the statement that they ‘used the needs of other people to develop my own ideas’ (56.7%). The statement with the most negative responses, ‘I was involved in presenting the solution to other people’ (18.8% disagree), perhaps reflects the fact that some Design Thinking activities were shortened due to time constraints.

Design Thinking has strong roots in constructionism and therefore the survey explored the extent to which students experienced constructionist elements in the activities they participated in. While students tended to agree that they ‘worked on something that I was interested in’ (3.89 average) and ‘I was able to choose what I wanted to do’ (4.09 average), the majority of students chose ‘neither agree nor disagree’ to the statements ‘I tried to solve an important problem which had no single solution’ (3.28 average) and ‘I invented a solution to a difficult problem’ (3.41 average).

The majority of students agreed (4.35 average and 5 median) that they had worked as part of a team and there were no notable parts of the survey responses to indicate that there were challenges in teamwork. They were similarly positive about the use of technology, sharing what they had done and supporting others. They were not bored and felt that they persevered with their projects. Using a t-test it was found that there was a statistically significant difference ($p<0.05$) between male and female students, with male students more likely to have agreed that they ‘liked sharing what I had done with other people’ (Table 2)

Table 2 Comparison of male/female responses to 'during the project I liked sharing what I had done with other people'

Gend......	Count	Average	Median	% N
Male	80	4.00	4.00	
Female	61	3.61	4.00	
Total (2)	141	3.83	4.00	1 2 3 4 5

Overall, the school interventions were successful when viewed in comparison to previous studies. The survey drew on the findings from Deliverable 2.1 regarding the challenges and frustrations students experience during Design Thinking activities in the classroom, identified in the literature. On the whole, students did not feel frustrated using the project technologies or working as part of a team. They mostly felt listened to and tended to like redesigning their solutions (although most chose 'neither agree nor disagree'). However, using a t-test, female students were statistically significantly ($p<0.05$) more likely to report listening to other people's ideas (Table 3).

Table 3 Comparison of male/female responses to 'I listened to other people's ideas'

Gend......	Count	Average	Median	% N
Male	82	4.10	4.00	
Female	60	4.42	4.00	
Total (2)	142	4.23	4.00	1 2 3 4 5

Students did not find it difficult to think of ideas and felt they knew what to do. However, there was an interesting statistically significant difference ($p<0.05$) with a small effect size between the attitudes of male and female students, with female students less likely to disagree with the statement 'I felt frustrated not knowing what to do" (see Table 4) suggesting less certainty.

Table 4 Comparison of male/female responses to the item 'during the project I felt frustrated not knowing what to do'.

Gend......	Count	Average	Median	% N
Male	81	2.15	2.00	
Female	60	2.58	2.50	
Total (2)	141	2.33	2.00	1 2 3 4 5

Following the trend seen in other research studies, students found that organising their time and being able to complete everything within the given time were more challenging and 27.7% felt they had not received feedback on how to work as a team.

Technology Developments

ChoiCo

The majority of students who participated in the survey had used ChoiCo during their Design Thinking project (79.2%). 50.2% of those agreed that ChoiCo was easy to use and 63.9%

agreed that they were able to use ChoiCo to achieve what they wanted. Tutorials, instructional videos and even printed instructions were common requests. A few students mentioned bugs in the tool. Clarity around the functionality of code blocks was requested and in terms of additional functionality, students suggested adding animations.

MaLT2

Most students that used MaLT2 had previous experience using the tool and agreed that it was easy to use and they could use it to achieve what they wanted. Writing commands was a challenge identified by students when asked how MaLT2 could be improved: "*Some commands are not very predictable concerning their outcome, for that I could use some help*". Suggestions such as documentation on the commands or guidance within the platform on how to correct mistakes were identified as possible improvements.

nQuire

The majority of students (40.5%, n=37) who used nQuire neither agreed nor disagreed that it was easy to use but the majority (62.8%) were able to use it to achieve what they wanted. Of the 28 respondents who had used nQuire, there was a clear split between those who could not identify any improvements to make and those who wanted it to be "*easier to use*" but gave no specifics.

SorBET

Only 6 students used SorBET. They strongly agreed that sorBET was easy to use but there was a clear split between those who felt they could use it to achieve what they wanted. When asked how SorBET could be improved, all five students who provided an answer agreed that no improvement was necessary: "nothing it [*sic*] amazing and easy to use please don't [*sic*] change it".

Skills

Students were asked a purposefully open question about what skills they felt they had developed during the project. Of the 135 participants who provided at least one answer (up to 3 skills could be listed), cooperation was the most referred to skill, followed by programming, teamwork, thinking and communication. A word cloud analysis of students' responses is provided in Figure 6. The top 19 skills mentioned by participants are listed in Table 5.

In terms of project development, it is perhaps more valuable to consider which skills are least frequently mentioned or not included in Table 5 below.

In general, students stated that they felt confident or more confident to use these skills in future projects. However, some noted that these skills were still developing their confidence with one commenting, "*I don't feel confident. This is not one of my strengths.*" Another stated, "*Not much! But I will not hesitate to participate again in similar projects.*" Another wrote, "*Not very confident, but better than before.*"

Figure 6 Word cloud of all responses to the item "List 3 skills you have developed during the project"

Table 5 Word frequency of skills students developed.

Word/phrase	Count	Similar words
Cooperation	45	Cooperate, cooperation
Programming	42	Programming, programs, coding
Teamwork	38	Team, teamwork, team working, teamwork, teamworking
Thinking	33	Think, thinking
Communication	25	Communicating, communication, communicator
Technology	17	Technology, computer
Problem solving	9	Problem solving, solving problems
Game making	9	Game making, make a game, making a game
Creative	8	Creative, creativity
Open minded	7	Open minded, mind open
Listening	6	Listen, listening
Time management	6	Time management, time organisations, organise time, manage my time
Respect	5	
Mathematical	5	Mathematical, mathematically, mathematics, maths
Collaborate	4	Collaborate, collaboration
Design Thinking	4	
Patience	4	
Reflection	4	Reflective, reflection, reflecting
Research	4	

Overall Views

Overall, students most students enjoyed the Design Thinking activity and most gave their projects 4 stars out of 5. Even those who were not interested in the topics enjoyed their experience, “*This project doesn't fit very well with my interests but it was a good experience*”. They felt they had learned a lot, from domain specific knowledge to 21st century skills.

However, few made any mention of learning about Design Thinking. Negative views tended to focus on the issue of time – not having enough time to complete their projects – and some students mentioned challenges with working in a team and not fully comprehending their tasks.

When asked what was the most interesting thing they learned, all students in Norway who participated in the cyber-security activity identified digital skills and knowledge which ranged from topic specific knowledge to programming skills and the project technology ChoiCo. In Greece, students found the topics of their projects interesting, developing their digital skills through creating a game and teamwork, particularly listening to others' and respecting different opinions – for example "*To cooperate in a team as well as to take into account the comments of others.*" (original: "*Να συνεργαζομαι σε μια ομαδα καθως και να λαμβανω υποψην μου τα σχολια των αλλων.*")

5.3 Professional Development

Professional development (PD) activities for qualified and student teachers took place at two sites: UGent in Belgium and NKUA in Greece. Overall, in both contexts, students valued the opportunity to engage with and learn about a new pedagogical approach (Design Thinking). In particular, they valued the role of 'empathy' throughout the Design Thinking process and the opportunity for themselves to collaborate with others from diverse backgrounds. However, students identified a number of barriers to them using Design Thinking as a pedagogy within their own classrooms. The reports for each are presented in Appendixes G and H.

5.3.1 Design Thinking

Time

In both cases, students raised issues about the amount of time available to complete the Design Thinking phases. At UGent students felt that they had too much time for each phase. This may be accounted for due to the session tutors realising that students had not fully engaged in the brainstorming activity and returning the class to it, meaning that more time was spent on this phase than initially planned for, resulting in a sense of dissatisfaction from the tutors and students alike with regards to the overall structure and timings of the workshop, yet students noted that there was a good workflow.

In Greece, the biggest issue related to time was in relation to whether it was feasible to implement Design Thinking activities in teachers' own classrooms. They noted that they themselves were unable to complete their games to the level they wanted and eventually presented a simpler game than they had originally planned. This closely relates to the issue of personal time-management raised in the school interventions, but also an awareness that students may not have the skills needed to complete all aspects of a Design Thinking project and need appropriate scaffolds.

Divergent Thinking

One of the challenges in the PD activities was engaging students in divergent thinking and specifically initial brainstorming. At UGent students wanted to quickly focus on 'the right solution' and get on with it, when it came to both brainstorming and iterating their designs, viewing brainstorming as an 'extra' task. While students at NKUA raised a concern that their own students would find it difficult to adjust their thinking to be open to conclusions that they might not have predicted as their own students are used to following a linear path. Choice making is not usually available to school students.

Productive Failure

Productive failure is another aspect that teachers in Greece felt would be challenging for their own students. However there was no strong evidence that this was an issue within the school interventions.

Empathy

The integration of empathy as part of the Design Thinking process in a practical and meaningful way was highly valued by teachers in Greece. They identified how it not only informed the initial divergent-convergent discover-define phases but the whole process, and marked it as a key feature which distinguishes Design Thinking from other project-based approaches. This is closely linked to the real-world context that frames a Design Thinking activity, both of which students found motivational. Yet, teachers also felt that they lacked resources to structure and motivate students in the empathy phase.

As a Pedagogy

In Belgium, in-service and pre-service teachers were least likely to value 'productive failure' as a pedagogic tool and those with experience indicated that they tended not to use hands-on/experiential approaches in their classrooms. By contrast, in Greece, productive failure, practical experiences, contextualised learning and group work were approaches that were already valued by teachers prior to the PD workshops. These are significant considerations as the existing beliefs of teachers are likely to inform their response.

In Belgium, students noted that it was unclear to them exactly what Design Thinking is and what relevance it has to their own subjects. The written responses to the survey highlight the barrier of siloed subject teaching to using Design Thinking as a pedagogy, while in Greece students from the Arts, Humanities and Social Sciences had difficulty in seeing the relevance of Design Thinking to their own subjects, noting that the examples they were given were primarily situated in the STEM domain. Yet, in both cases, students valued the fact that their own experience of a Design Thinking activity was not like a typical class and noted that they gained knowledge and skills as they worked through each phase, with one student noting: "*The process is more important than the product*".

In Greece, teachers suggested that a simplified version of Design Thinking may be necessary for them to use it within their own settings due to time constraints.

5.3.2 Technology

Rapid Prototyping

In both Greece and Belgium, most students had a positive sense of self-efficacy when it came to engaging with technology in general. In Greece, they recognised the constructionist nature of the project technologies which facilitated rapid prototyping, yet students felt they did not have sufficient time to explore each of the project technologies. Indeed, they felt that the use of digital technologies was essential for making and sharing rapid prototypes.

Added Value

In Belgium, where students only engaged with ChoiCo, views were mixed about its potential in the classroom due to technical problems they encountered and a lack of clear benefits in using the technology and the time taken to create something meaningful. In Greece, students raised the issue of technical problems and ease of use, plus the limited possibilities for their use, with students outside STEM subjects struggling to identify their relevance, yet they were more likely to consider using the project technologies with their own students.

Supports

The video tutorials that were provided to students in advance of the class in Belgium were valued which aligns with their pre-survey results on self-efficacy, as were the supporting how-to guides. There were some suggestions on improving the resources such as providing them further in advance, making them shorter and including English subtitles.

5.3.3 21st Century Skills

Both groups of students expressed a mixed sense of self-efficacy when it came to their own 21st Century skills. While numbers are too small to calculate meaningful statistical differences, they tended to lack confidence in solving problems that have no single correct solution and analysing different arguments, perspectives or solutions to a problem. This may, in part, explain why they raised these as potential issues for their own students.

Teamwork

Teamwork was a skill that many students identified as having developed during the workshops. In both cases, students collaborated in multidisciplinary groups which they valued and were identified as supporting their **communication skills** (speaking and listening) and **critical thinking skills**. However, larger groups were more likely to be less engaged and less collaborative than smaller groups. This was particularly apparent in the findings from UGent where teams comprised 6 and 7 students. One factor that appeared to support engagement and collaboration was a member of a group who assumed a leadership role at some point during the activities. In some cases this role rotated between students during each phase but crucially those who assumed this role enabled their group to work collaboratively.

Assuming a role within the group is also a key point raised by teachers at NKUA or their own students, noting that the roles would need to be clearly defined by the teacher.

Communication

Students at UGent felt they learned the most from their peers through the process of discussing the project with their team. Similarly, students at NKUA observed the same, emphasising the value of interdisciplinary groups, with one teacher noting: "*Communication and different opinions made the process more enjoyable and motivating".* They also identified how empathising with others outside their group in the Discover phase, opened up communication within their groups.

What was perhaps surprising was that no student at NKUA considered communication skills relevant to the Deliver phase, but working with others was by almost all students. Also notable was that prior to the PD course students had a low self-efficacy in terms of their ability to present to others, yet they particularly valued this phase as an opportunity to gain feedback, which was rewarding, motivating and enjoyable. As one student noted "Getting feedback about the topic was when I learned the most". Yet communication is essential to working with others, presenting and engaging with feedback.

Time Management

As previously mentioned, students in both contexts identified personal time management as an issue. Students in Greece stated that they found it difficult to organise their time, suggesting that they and their students may value guidance and time to consider how to manage their time. Equally, it may suggest a mismatch in expectations between tutors and students. Working to deadlines is a valuable skill to develop and PD courses do not have unlimited time, in the same way teachers and students in schools do not and nor do designers, engineers, etc.

Reflection

In Greece, teachers noted opportunities for both themselves as designers to engage in reflection through the process of designing a Design Thinking activity, and opportunities for their students as designers to reflect as they engaged in the Design Thinking activity. The four phase structure of Design Thinking was identified as facilitating this reflection. Yet they also felt that it would be challenging for their students to identify their own mistakes, correct them or to reflect on their actions as students are not effective at this in their own work or familiar with it, depending on the subject area.

It was noted that in Greece there was no space for teachers to provide their own students with opportunities to revise their work based on feedback within the curriculum, so this was a skill students were unlikely to have and would need support to develop. Providing students with a structured approach, guide or facilitating questions were suggested as potentially valuable.

Creativity

While students noted creativity as a skill they felt Design Thinking supported across the four phases, it was less evident in their interviews, observations and survey comments by comparison to the aforementioned skills. Developing a shared understanding of what is meant by creativity, the different forms of creativity and considering ways in which creativity can be meaningfully assessed is a notable challenge within the evaluation, not just for the research team but for teachers and students engaged with the project.

6 Initial Literature Review

Prior to discussing the recommendations which have emerged from the evaluation findings, this section provides an update on the initial literature reviews carried out under Task 7.2 as they contribute to some of the recommendations for the evaluation in subsequent cycles.

Three systematic literature reviews aim to provide the project with the latest instruments for the evaluation of 21st Century Skills, Design Thinking and Digital Competencies, to inform the co-design and development of data collection instruments for use in the teachers' evaluation toolkit (Task 7.3), surveys (Task 7.4) and Learning Analytics platform (Task 4.4). While TCD leads the team, the work is distributed with two people at TCD leading the first two reviews and one person at NKUA leading the third. This ensures that specialists are leading the individual review teams but there is a consistent approach to all three reviews.

The three review leads collaborated to develop research questions and search strings that were both specific to their topics but would enable reliable comparison at later stages. The search strings were used in several education, psychology, social science and computer science databases. These resulted in a total of 13 172 results for the 21st Century Skills review; 5 587 results for the Design Thinking review and 10 144 results for the Digital Competencies review. While screening is still ongoing, the following points quickly became evident which need to be taken into consideration in the development of evaluation tools in Years/Cycles 2 and 3:

- Instruments are often designed and validated for use with adults and then used with few modifications or revalidation with young people.

- Some researchers have proposed using 'anchoring statements' to increase the reliability of student responses to Likert scale items, due to the "fuzzy" nature of terms such as 'creativity', however they may increase the overall time it takes for participants to complete surveys.
- There is substantial cross-over between instruments measuring 21st Century Skills, Design Thinking and Digital Skills.

7 Discussion and Recommendations

The results presented above provide substantial insight into the outcomes of the co-design, school intervention and PD activities. There is a strong indication that young people engage meaningfully and enjoy the Design Thinking approach, however teachers struggle to find its value in terms of their own subject specialisms and the substantial time it takes. Reflecting on the analysis of previous research into the use of Design Thinking in education, presented in Deliverable 2.1, it is clear that some of the opportunities and challenges identified above and recommendations outlined below align with the existing research. For example, Milara et al., (2020) suggest that an emphasis on reflection is beneficial for students, enabling them to participate, find new and creative ways of learning and get excited about learning. In essence, this aligns with Seymour Papert's belief that even very young children are capable of and should learn about how they learn.

Assessment of children's learning is a challenge across the research, a challenge which remains within our own evaluation and one which requires particular attention if teachers are to use Design Thinking in their own classrooms. As noted by Veldhuis et al (2022), teachers need help connecting assessment activities with the learning objectives they have established for their students, whether formal or informal assessment. However, an important question remains open – what should be the focus of assessment, who is best placed to do that assessment and how can it be achieved? The literature review has already highlighted that 21st Century Skills and Design Thinking are often assessed through self-reporting and that a students' own sense of self-efficacy may be a valuable approach but one which is inconsistent due to vary factors in a person's life. Whether there are quantifiable relationships between Design Thinking dispositions and Digital Skills or 21st Century Skills as suggested by Tsai and Wang (2021) requires further study, however this evaluation has revealed opportunities within Design Thinking phases for students to develop certain 21st Century Skills.

In terms of professional development, we know that Landwehr Sydow et al., (2021) suggest that teachers need to develop a mindset which includes openness, curiosity, responsiveness and a willingness to use technology, in order to view creation as a learning *process* rather than an *output*. While that was acknowledged by some teachers following our own PD activities, their resistance to divergent thinking was a significant barrier to their own engagement with the Design Thinking process.

The need for teachers to have digital skills and a common language to talk about Design Thinking does not appear to have been a significant barrier for teachers, unlike in other studies (Smith et al., 2016; Landwehr Sydow et al., 2021). This is most likely due to the design of the workshops to give and provide opportunities to develop relevant knowledge and skills. However, it is not clear to what extent they could take this knowledge and apply it to their own development of Design Thinking activities for their classrooms. Xiao et al (2022) found pre-service teachers found it challenging to connect design challenges to real-life contexts, while Sabuncuoglu (2020) found that teachers needed support to figure out how the rationale, objectives and content of the curriculum aligned with Design Thinking and emerging technologies.

7.1 Limitations and Challenges

As with any approach to research and evaluation, there are limitations. The first year of ExtenDT² has been no exception to this, however mitigation measures were designed into the approach to reduce their impact. For example, the use of video and audio recording equipment can be challenging in certain contexts thus, while less complete, partners undertook written observations which either supplemented these recordings or replaced them. The first year is also an opportunity to pilot data collection and analysis approaches. With a range of research experience and expertise across the consortium, together with a range of research contexts, partners require an opportunity to trial approaches. Similarly, instruments such as surveys which are validated in advance still need to be piloted in the research setting. An exploratory case study approach was chosen as it enabled piloting not only of the data collection tools but also the pedagogic approach and digital tools. A limitation of this approach is that data from Year 1/Cycle 1 cannot be merged with subsequent data collected, however this is not our aim. Instead, the evaluation in this Year/Cycle intends to inform the development of WPs 3, 4, 5, 6 and 7, as per the Design-Based Research approach of the project as a whole.

Beyond the general approach to the evaluation, there were some partner specific challenges. The most significant challenge for one partner (LNU) was the need for ethical approval from the Swedish Ethical Review Board. This is a long process resulting in a detailed application to be submitted to this national board where many details of the study need to be established in advanced to avoid further delays due to requests to provide further details to be processed and considered for the application to progress.

Another ethical issue emerged when it was unclear which participants had consented to data collection, prior to processing the post-intervention survey. While it was clear that more students had parental consent to participate, students did not use a standardised approach to identifying themselves (by name or student ID). For this reason only 7 participants' data were included in the post-intervention survey data set, the rest were destroyed.

Several partners struggled with initially recruiting teachers who were interested in the project and to maintain their engagement from the co-design process through to the school interventions. One of the main challenges reported was that teachers struggled to see the relevance or added value of either the project technologies or the Design Thinking process to their subject.

In terms of the data collection process, in one case, school restrictions meant that video and audio recordings could not take place, which was mitigated by the use of written observations. The length of surveys was identified as a challenge, taking time away from school interventions. In one case, the surveys were still being completed by students participating in PD activities whilst others had already commenced the workshop activities which is both ethically and educationally problematic. These cases highlight the importance of treating the research as an 'additional' activity to the interventions themselves, requiring personnel and dedicated time.

Reflecting on the data analysis process, there is a clear challenge around evidencing learning. While teachers have designed activities with specific intended learning outcomes in mind, it is unclear from the activity plans how these are to be assessed. Although evidence can be gathered through surveys and interviews, the latter is time consuming and unrealistic for teachers and surveys can lack the granularity that teachers need to track progress.

7.2 Recommendations

The findings presented above highlight a range of areas for further development and consideration within the project. The recommendations herein are written in recognition that evaluation outcomes may be context specific and in-turn the implications for the project may not be broadly generalisable. However, there is a need to generate recommendations that can inform the project developments. What is presented below are a set of recommendations structured according to the projects' main themes of Design Thinking Pedagogy, Technology and 21st Century Skills.

7.2.1 Design Thinking Pedagogy

1) Consider whether students need to explicitly learn about Design Thinking as the process with which they are engaging. (WP3, WP5 & WP6)
    a. **Activity plan template** – should knowledge of Design Thinking be a learning outcome, why, in what circumstances, how could this be facilitated and assessed?
    b. **PD workshops** – ensure that students are provided with both the theory and practice elements of Design Thinking to inform their own engagement and professional practice.
    c. **Evaluation** – consider whether and how to assess students Design Thinking knowledge/mindsets.

2) Develop activity planning as a reflective process involving its own initial rapid prototyping through a simplified activity plan template or activity model. (WP3, WP5 & WP6)
    a. **Activity plan template, PD workshops and co-design** – explore with teachers the possibility of using a Design Thinking activity model which provides parameters and enables teachers to expand, contract or iterate phases through their own rapid and iterative lesson design process.
3) Provide sufficient time and guidance for students to fully engage in the Discovery phase. (WP3, WP5 & WP6)
    a. **Activity plan template** – provide prompts to teachers to consider the amount of time given to this phase in relation to the activities and technologies students are expected to engage with and the intended learning outcomes.
    b. **PD workshops** – provide students with a flexible structure in which to engage in Discovery activities, clear time limits and expectations.
4) Ensure that sufficient time is provided in the Deliver phase for students to present their solutions, gain feedback and act on feedback. (WP3, WP5 & WP6)
    a. **Co-design, activity plan template and PD workshops** – highlight the importance of this phase for students.
    b. **Resources** – identify methodologies to facilitate these activities and create tools to support students.
5) Identify ways to cultivate a divergent thinking mindset. (WP3, WP5 & WP6)
    a. **PD workshops** – provide a short, low-pressure and fun activity to introduce students to brainstorming before they engage in brainstorming for their project. This could double as a valuable team formation activity.
    b. **Activity plan template** – encourage teachers to reflect on the time students will require to create and iterate their prototypes.
    c. **Resources for teachers** – include activities or resources for teachers to learn about the challenges of divergent thinking and practical supports/activities for their students.
6) Create practical examples/vignettes to demonstrate the relevance of Design Thinking to Arts, Humanities, Social Sciences and STEM subjects within schools. (WP3, WP5 & WP6)
    a. **Resources for teachers** – provide brief overviews of projects implemented in various subject domains for teachers and student teachers.
    b. **Co-design and PD workshops** – use vignettes to stimulate engagement and idea generation.

7.2.2 Technology

1) Consider the extent to which students (adults and young people) need to engage with technology throughout the Design Thinking phases.

a. **Activity plan template & PD workshops** – evaluate what the time constraints and cognitive load requirements are versus the benefits of engaging with more than one technology, especially when that technology is new to students and/or teachers.
b. **Co-design & PD workshops** – be able to provide suggestions to teachers on which technologies can successfully facilitate each phase and provide examples.

2) Identify ways to build in time and supports for teachers and students to familiarise themselves with project technologies in low-pressure, yet meaningful ways. (WP3, WP4, WP5 & WP6)
   a. **Activity plan template & PD workshops** – Provide time for students to sandbox or provide short structured activities to enable them to become familiar with the functionality of new technologies during the Discover phase, in addition to the use of video and written guides.
   b. **Co-design and PD workshops** – consider whether students would engage with a flipped classroom approach to introduce them to technologies before first use.
   c. **Teacher and student resources** – Develop brief introductory videos to the technologies, step-by-step guides, clarify the added value of the technologies and provide exemplars of their use in relation to each Design Thinking phase.
3) Remove the need for passwords and codes which students easily forget. (WP4)
4) Add an easy-to-use sharing functionality. (WP4)
5) Consider how the project technologies can be used to provide automated assessment of learning. (WP4)
6) Review our expectations and the expectations we implicitly pass on to teachers (and they in turn to their students) regarding the outcomes of a Design Thinking project and project technologies. (WP2, WP3, WP4, WP5 & WP6)
   a. What does the 'final' product look like in the deliver stage? Should we review our language?
   b. Do we need to use every project technology?
   c. What are the limitations of the technologies and how will the extensions to these technologies address these limitations?

7.2.3 21st Century Skills

1) Identify effective pedagogic strategies to explicitly develop 21st Century Skills within Design Thinking phases. Avoid assumptions that students (whether adults or young people) know how to work in teams, self-organise, etc. Or that they will gain these skills by simply participating in Design Thinking activities without explicit guidance. Students need supports to learn and develop 21st Century skills, within the context of meaningful Design Thinking projects. (WP2, WP3, WP5 & WP6)

a. **Activity plan template & co-design** – when identifying 21st Century Skills to include in the intended learning outcomes, teachers should be prompted to consider how they will support the development of these skills and assess them.
b. **Resources for teachers and students** – develop resources and approaches for teachers and students in the areas of:
    i. Time management
    ii. Divergent thinking
    iii. Teamwork – communication skills and roles
    iv. Providing and responding to feedback
    v. Reflection
c. **PD workshops** – provide equivalent supports for pre-service and in-service teachers, identify for them or have them reflect on their own sense of self-efficacy and challenges they face.

2) Develop approaches to the orchestration of teamwork, considering the ways in which mixed knowledge, skills and experiences can be valued. (WP3, WP5 & WP6)
    a. **Activity plan template** – Develop ways for teachers to consider the relationship between group size, internal makeup of the groups, access to technology and other resources, against the activities the groups are expected to engage in.
    b. **Resources for teachers** – Develop tools to scaffold teamwork, collaboration and communication.
3) Identify ways in which the project technologies could facilitate. (WP4)
    a. Time management
    b. Divergent thinking
    c. Team cohesion, particularly in sharing and responding to ideas and reaching a consensus
    d. Feedback between peers/end users and students
    e. Reflection
4) Empathy is an essential component throughout the Design Thinking process and may provide a way for students to engage in reflective and critical thinking, enhancing rapid prototyping activities and increasing students' comfort with productive failure. (WP3, WP4, WP5, WP6 & WP7)
    a. **Activity plan template and teacher resources** – identify ways in which students could be prompted to re-engage with the results of the Discovery phase as they engage in prototyping.
    b. **Project technologies** – explore how students could be prompted to re-engage with the results of the Discovery phase as the engage in prototyping.

   c. **Evaluation** – explore whether there is a relationship between empathy, reflective and critical thinking, rapid prototyping activities and productive failure.

5) Consider the role of reflective thinking activities for students as an opportunity to both evidence learning and engage students in critical thinking at key points throughout the Design Thinking process. (WP3, WP4, WP5, WP6 & WP7)
   a. **Activity plan template & PD workshops** – Include prompts for teachers to engage their students in relevant reflective tasks linked to evidence of learning.
   b. **Resources for teachers** – Provide example activities for teachers to use with their students.
   c. **Evaluation –** Provide flexibility within the evaluation for a range of reflective tools to be used; work with WP3, WP5 and WP6 to develop tools which can be used to meet requirements and provide evidence of learning.

7.2.4 Evaluation & Ethics

1) Identify ways to successfully communicate with teachers, parents and young people about the project technologies, their potential value and risks (WP3, WP4, WP5, WP6, WP7 & WP9)
   a. **Resources for stakeholders** – develop appropriate resources for each stakeholder group to introduce them to the project technologies and be transparent on their use and value.
   b. **Evaluation** – establish stakeholders' attitudes to AI, LA, AR, etc., in education to inform the creation of resources, engagement with potential participants.
2) Where possible, evaluation activities should happen outside the Design Thinking workshops. (WP5, WP6 & WP7)
   a. **School interventions and PD** – avoid conducting surveys and interviews when students should be engaged in Design Thinking activities by identifying opportunities prior to and following the workshops when data can be collected.
   b. **Evaluation** – identify potential risks to research regarding informed consent and sample sizes and acceptable distance from the action for meaningful data collection.
3) Identify ways for teachers and students to evidence learning as part of their Design Thinking activities and practices. (WP3, WP4, WP5 & WP7)
   a. **Activity plan template, co-design & evaluation** – identify opportunities, approaches and tools which have a low-impact on or preferably enhance the activities of students.
   b. **Project technologies** – identify ways in which project technologies can be used to evidence learning automatically and manually.

4) Consider that in light of ethical approval delays the Year/Cycle 2 and 3 evaluation plans may need to be revised.
    a. **Evaluation & ethics** – explore with partners affected by institutional and national review committee delays ways to streamline the process in the coming design cycles.
5) Explore with teachers the requirements of a sustainable evaluation toolkit (WP3 & WP7)
    a. **Evaluation** – identify effective pedagogic strategies and existing validated instruments which teachers can consider using within their own classrooms.
    b. **Evaluation & co-design** – identify what is valuable for teachers to evaluate as part of their practice and their students' learning.

8 Conclusion

Overall, the evaluation demonstrated that students and teachers valued the Design Thinking approach and project technologies clearly provided added value as students engaged in rapid prototyping. The evaluation has also enabled the project team to identify areas where teachers and students may require specific scaffolds and additional time to fully engage and benefit from the process. Students had opportunities to use 21st Century Skills, but they often lacked supports to develop those skills. Subject specialisms and educational contexts present perceived barriers to implementing Design Thinking and using the project technologies within the traditional classroom as part of the curriculum. This is a challenge that the project partners will need to engage with meaningfully if they are to engage sufficient schools and teachers to meet the projects' key performance indicators in the coming Year/Cycle.

8.1 Next Steps

In Cycle 2 the evaluation shifts from exploratory to instrumental. Based on the recommendations set out herewith, subsequent discussions within the project consortium, and with consideration of their own cultural context and pilot experiences, partners will identify (in collaboration with teachers where possible) elements that they intend to develop and trial in school interventions and PD activities in Year/Cycle 2 of the project. These will become the focus of the instrumental case studies to be implemented and evaluated.

Data collection approaches will remain broadly the same, although there will be flexibility depending on the case study focus. For example, if the focus is on whether project technologies support time management, interviews and observation approaches will focus on this. If the focus is on assessment, classroom observations may be scaled back to relevant points in the action.

The teachers' toolkit will be initially developed and piloted in Year/Cycle 2. This is highly dependent on sustained engagement with teachers throughout the year which has been a challenge in Year/Cycle 1. The first step will be to identify teachers who have already participated in ExtenDT² activities who are interested in participating with their students in the coming year.

As we move towards the use of an Authorable Learning Analytics system, there are increasingly complex ethical questions that need to be addressed, in particular surrounding informed consent but also new opportunities to gain data to inform the project developments. While this is a matter for WPs 4 and 9, it has a substantial impact on WP7 activities and will need the engagement of all project partners as well as stakeholders.

More broadly the evaluation has implications for the project as a whole, from initially engaging and maintaining teachers' interest in the project as potential participants, through to technical developments and professional development. This will require regular communication and collaboration between all partners.

8.2 RRI Statement

Responsible Research and Innovation (RRI) is interactive, iterative, and involves high levels of transparency with regular reflection on processes and goals. Given the rapidly changing technological landscape, we aim to anticipate potential issues before they arise. The project design has RRI embedded throughout in the following ways: in its structure and organisation; its ambitions in terms of engaging young people in design thinking for societal challenges; its engagement with schools which allows equitable engagement of young people regardless of gender and an opportunity for young people to engage meaningfully with scientists on topics within STEM education; the project design involves co-design and co-production; there is active engagement with the public through dissemination activities; the data management plan (DMP) emphasises the importance of open access data and publications; and finally the project team is actively involved in considering emerging ethical issues throughout the project, guided by an independent external advisor and ethics advisory board. Throughout our activities we aim to be diverse and inclusive, for example, listening to and including diverse groups of people in decision making processes. Through our deliverables, project newsletter, engagement activities website and the research itself, we aim for open and transparent communication. The project partners regularly reflect on the motivations for our research against a backdrop of the wider ethical and societal context that the research is located in. We aim to be responsive and adaptive to the changing needs of our stakeholders and re-evaluate the research trajectories in light of new evidence.

Ensuring the relevance of our research for our stakeholders is essential and achieved through co-production activities which will be increased in Year/Cycle 2 with the development of a teachers' evaluation toolkit and co-design of instrumental case studies, with teachers. Participation in school interventions and participation in the research is close to 50:50 gender split (with 5 participants choosing 'other/prefer not to say').

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