PLAYING WITH PROTONS GOES DIGITAL

ASSESSMENT GUIDE

Co-funded by the Erasmus+ Programme of the European Union

PLAYING WITH PROTONS GOES DIGITAL is a project funded by the Erasmus+ Programme of the European Union (REF: 2020-1-IT02-KA226-SCH-095525). The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Document Control Page	
WP/Task	Tasks T1-T5
Title	PLAYING WITH PROTONS GOES DIGITAL Assessment Guide
Due date	30/05/2023 Extension of the project to 30/11/2023
Submission date	30/11/2023
Abstract	This assessment guide outlines the methodology and evaluation tools and activities for teachers designing and implementing activities, measuring the effectiveness of increasing student interest and motivation in science, as well as student understanding of key scientific ideas such the microcosm, big ideas in science, scientific discoveries. The evaluation guide includes a series of instruments to assess the impact on the project to teachers and students. The Playing with Protons goes Digital approach studies the expected impact from multiple perspectives, allowing comparisons between various educational settings and contexts, thus allowing for a more comprehensive understanding of STEAM.
Author(s)	Iliana Ntovolou (EA), Sofoklis Sotiriou (EA), Dr. Pierluigi Paolucci (INFN), Dr. Flora Di Martino (Città della Scienza)
Contributor(s)	Dr. Flora Di Martino (Città della Scienza), Dr. Jorge R. López Benito and Dr. Enara Artetxe González (Creativitic), Dr., Giovanni Organtini (INFN),
Reviewer(s)	Dr. Sofoklis Sotiriou (EA), Dr. Pierluigi Paolucci (INFN)
Dissemination level	☐ internal ☒ public ☐ confidential

Document Control Page			
Version	Date	Modified by	Comments
0.1	30.09.23	P. Paolucci	Table of Contents – First Draft
0.2	15.11.23	Iliana Ntovolou	Final Draft - Comments and Improvements
FINAL	30.11.23	S. Sotiriou	Final Version

TABLE OF CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

1

ABSTRACT

1 ABSTRACT

This Evaluation and Validation plan have been developed in the framework of the Intellectual Output 4 of the Playing with Protons goes Digital project, to address the need for assessing and validating the approach as educational practice. The scope of the IO4 is to address the evaluation and validation of the Playing with Protons goes Digital approach while its educational products implemented. This evaluation and validation plan considered all the activities realized in all the areas of the project: the scenarios design, the methodology and implementation of the educational AR activities. For assessing the approach, a set of evaluation and validation tools have been developed for the implementation phase project and exploited by the partners involved in this phase. The assessment plan defines the aspects of the project's impact and established and outlines the methodology and criteria adopted.

This report provides evidence of how well our approach, methodology and teaching materials, the so-called scenarios and AR tools, worked for students, teachers, and schools. In a nutshell, the results of our evaluation suggest that using AR tools improves science motivation and interest of students, and training teachers to use the Playing with Protons goes Digital project approach works well, but schools still need to make some organizational changes to use it optimally towards eliminating the gap between formal education and informal learning.

2

INTRODUCTION

2 INTRODUCTION

The last pandemic has caused major disruptions in school education globally. Teachers have been tested to their limits to keep offering their students high-quality distance learning activities. Many schools were challenged to continue providing remotely accessible and engaging science learning experiences in collaboration with outreach programs offered by large research institutes, science centers and universities.

In the current situation where traditional methods of education are disrupted, how can collaborative science learning activities involving schools, non-formal education institutions, and informal science education providers be effectively implemented? Are there ICT tools and practices that can enhance and sustain the science interest and motivation of young learners?

We believe that the rapid shift to online teaching and learning due to last pandemic presents schools with a unique opportunity to grasp the transformative potential of new digital technologies to enable engaging and resilient hybrid STEAM learning environments. But this is by no means a straightforward process.

In response to the educational disruptions caused by the pandemic crisis, the Playing with Protons goes Digital project envisages that every student deserves a digitally ready school that also has the capacity to act as an open innovation hub for the development of 21st century skills within an integrated learning ecosystem that capitalizes on the strengths of both formal and informal science education experiences.

Bringing together an international consortium of partners with a proven track record and passion for bringing innovation into the classroom, the project aims to evaluate the use of augmented reality (AR) digital technologies, appropriately framed and scaffolded, to foster inquiry-based science teaching and learning.

Playing with Protons goes Digital is an EU-funded Erasmus+ project answering to the call of the European Commission for digital education readiness through the enhancement of online, distance, and blended learning in school education by: (a) supporting teachers and educators to develop digital competences; and

(b) safeguarding the inclusive nature of digital learning opportunities to respond to the circumstances created by the COVID-19 pandemic. The project is led by INFN and carried out for a two-year and a half period (June 2021 to Nov 2023) by a network of five partners from four European countries (Italy, Greece, UK, Spain).

Playing with Protons goes Digital aims to address science teaching and learning by means of exciting digital technologies – specifically Augmented Reality (AR) tools and artefacts – by teachers working with hands-on and minds-on activities and experiments scaffolded by creativity-enhanced inquiry-based methodologies inspired by cutting-edge science in large research infrastructures (e.g., INFN, CERN) taking into consideration both remote support and working in the classroom.

Our approach aims to improve teacher digital skills, in particular content design and delivery skills, and their ability to respond to the demands for science teaching that not only enthuses young minds but also informs them about the inextricable relevance of science to society and encourages students to consider careers in STEM professions. The project places explicit emphasis on remote support by enabling all schools to: (a) work with engaging STEAM activities; (b) collaborate with universities, research centers and informal science organizations using open digital tools; and (c) access exciting open content that can be delivered by teachers remotely during closures or outside teaching hours. In doing so, our approach fits the KA2 Erasmus+ Horizontal Priority of Innovative Practices in the Digital Era and the field-specific priorities of Strengthening the Profiles of the Teaching Profession and Increasing the Level of Achievement and Interest in STEM.

Our interdisciplinary approach to science teaching and learning places high emphasis on the cultivation of teacher digital leadership and resilience through the optimal use of ICT that not only responds effectively to the “new normal” but is also sensitive to the cultural and environmental contexts that affect teaching and learning in diverse settings. We, therefore, aim to offer schools, including those in remote and rural areas, the ability to: work with engaging STEAM activities; collaborate with large research institutes and informal science organizations; and access exciting open digital content delivered by teachers and educators remotely and uninterruptedly.

Based on the implementation activities that made use of the AR materials and 11 different activities called scenarios developed in IO2 and IO3, this output provides qualitative and quantitative evidence to support two key objectives: (a) Introducing the inquiry-based method through a combination of STEAM-ART and AR/VR activities into the school curriculum, giving additional educational value to the school process and serving as a demonstration of best practices (b) the effectiveness of increasing student interest and motivation in study science.

The Playing with Protons goes Digital project trained 232 teachers, while 131 of them actively piloting and implementing the approach, methodology, and tools in 40 schools. 648 students actively participated in the project activities. Through a thorough analysis process, insights, and feedback from 421 of these students have been documented in this report.

The deliverable of the IO4 documents the impact and effectiveness of the Play with Protons goes Digital approach to bridging formal and informal science teaching and learning at two levels: student and teacher.

This report presents evidence showcasing the effectiveness of our methodology and the educational resources designed for both students and teachers. This document outlines the impact assessment framework for the Playing with Protons goes Digital project. The methodology described is drawn from the current interlinking evaluation methodologies on organizational change and educational practices in science education. The proposed methodology aims provides the information on how to assess the impact of Playing with Protons goes Digital project at two levels:

- At teacher's level (use of the AR tools developed and connect them with curricula activities) and
- At the student level (interest and motivation in science).

The proposed assessment methodology offers the general framework for validating of the activities done Playing with Protons goes Digital project.

3

METHODOLOGY

3 METHODOLOGY

The methodology described is drawn from the current interlinking evaluation methodologies on educational practices in science education. The proposed methodology provides the information on how to assess the impact of the activities and educational tools elaborated during the Playing with Protons goes Digital project at student level (interest and motivation in science).

The Playing with Protons goes digital school-based activities are based on sparking interest and motivation; understanding scientific content and knowledge; engaging in scientific inquiry method; reflecting on science; using the tools and language of science; identifying with the scientific enterprise. In this framework the project team was study students' attitudes (interest and motivation) as well as the development of crucial skills (e.g., collaboration and problem solving).

To collect quantitative data, an evaluation template with standardized questions and reflection points has been developed. During evaluation, the main issues to consider are being:

- How easy or difficult is to include these kinds of activities in the curriculum?
- How easy or difficult is to familiarize the teachers with the process and the technology?
- Was the technology friendly, or no?
- What are the findings about students' motivation?
- How easy or difficult is for students to act as creators of AR content?
- Has their intrinsic motivation increased?

Before describing the assessment methodology, we are describing the context of implementation of the project. This is based on a analysis of the current situation related to the use of advanced technologies in school classrooms in the participating schools.

3.1 NEEDS ANALYSIS

At beginning of the project, a short survey (needs analysis, see Annex I) was addressed to primary and secondary school teachers, head teachers, teacher trainers and educators to collect their feedback on the experiences, challenges, and opportunities in their teaching practice as the world adapts to the "new normal" caused by the COVID-19 pandemic. Within the project, the emphasis is on building teachers' digital competences by providing teachers and educators with an integrated toolkit that would enable them to co-design online creative STEAM resources that "speak" to the digital habits, needs, and interests of their students.

From the results obtained was clear that the AR technology was known but not used at all at school in all the four countries. From Figure 3 1 we can state that AR or VR technologies are known by 70% of the respondents but from Figure 3 2 we see that only 18% of them used these technologies as teaching support.

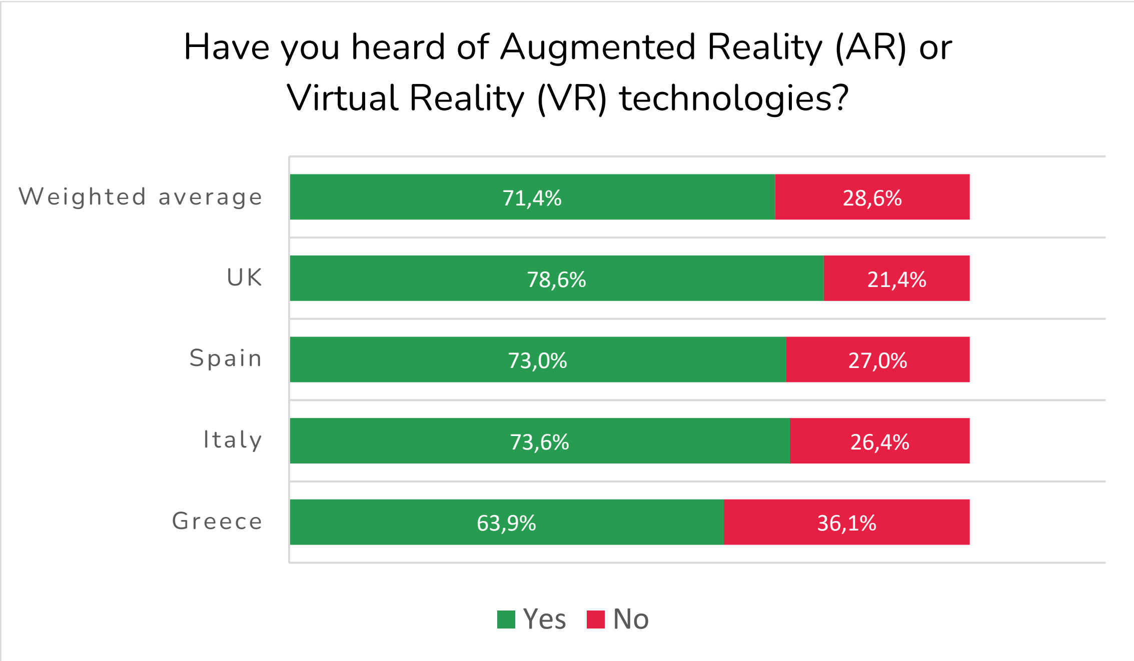


Figure 3-1 Percentage of respondents informed about the AR/VR technologies per country.

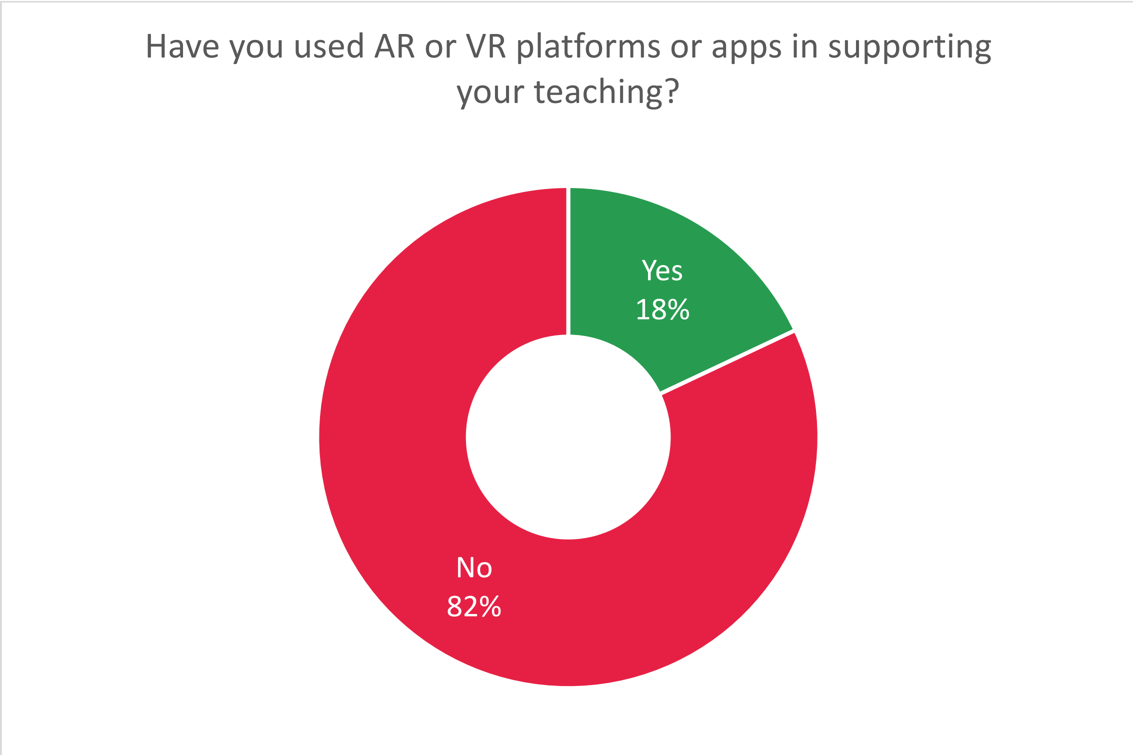


Figure 3-2 Average percentage of respondents informed about the AR/VR technologies.

A second important message (Figure 3-3)) we got from the need analysis was the very large interest (64% of respondents) in learning about AR/VR technologies and about the possibility to have a freely available digital toolkit with exciting STEAM activities inspired by cutting-edge science at world-renowned laboratories that can support both traditional and remote teaching.

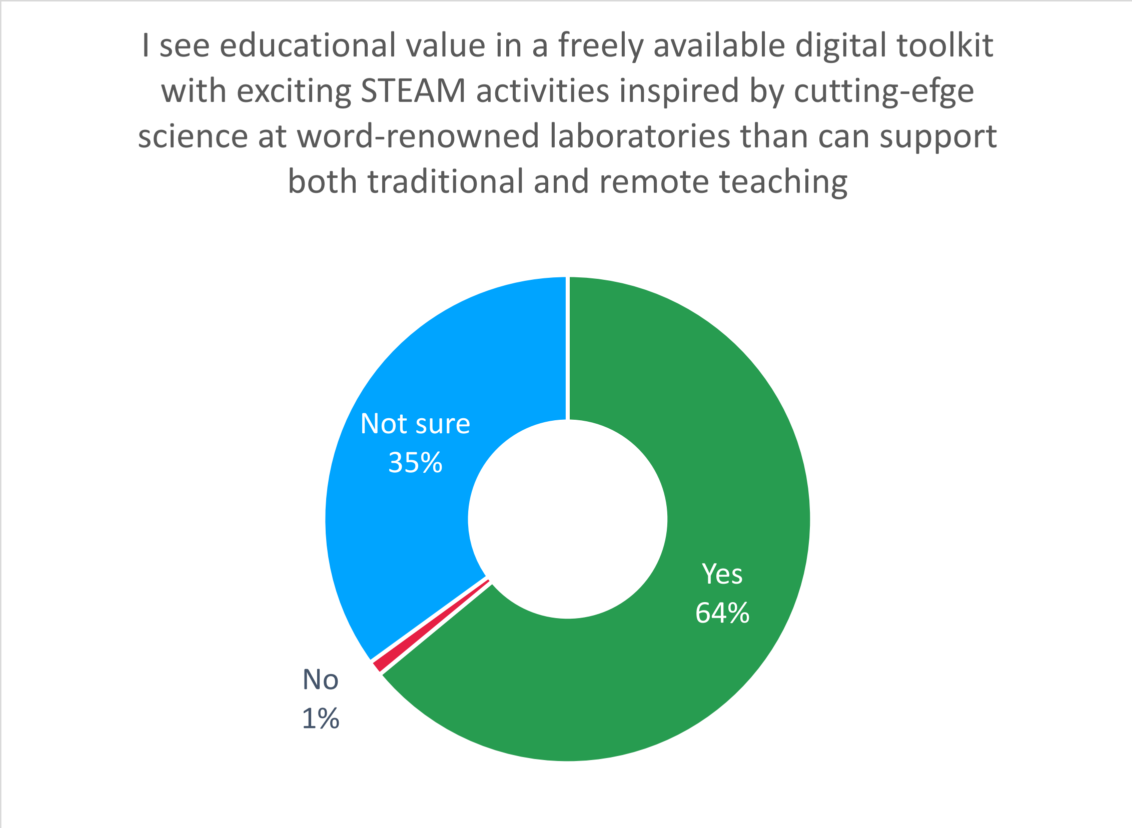


Figure 3-3 Average percentage of respondents interested in having a free digital toolkit with STEAM activities included.

3.2 ASSESSMENT METHODOLOGY AND EVALUATION TOOLS

The assessment methodology was aiming to assess the teachers' acceptance of the proposed intervention and the impact on students' interest and motivation. We have analyzed teachers views after their participation to a series of events (Multiplier Events, ME) organized by the project and the students' data before and after the intervention in the selected schools. We have focused on the development of students Interest and Motivation.

Three different Tools are designed to collect quantitative data from teachers and students:

- Questionnaire to evaluate the local Multiplier Events (Annex II)
- Teacher's reporting questionnaire (Annex III)
- Student questionnaire pre/post activities (SMQII pre (Annex IV), SMQII post (Annex V, IMI (Annex VI))

This analysis provides evidence of how well our approach, methodology and teaching materials for students, teachers, and schools. In a nutshell, the results of our evaluation suggest that using AR tools helps students learn better, and that training teachers to use AR tools and scenario works well, but that, both schools and informal science engagement organizations still need to make some organizational changes to use it optimally towards eliminating the gap between formal education and informal learning. One key takeaway from our evaluation is that digital education is considered by most teachers who collaborated with us as an innovative and cost-effective pedagogical approach to empower students, especially those who tend to be left behind and motivate them to learn science "outside the box". A second takeaway is that one size fits all approaches may not be efficient because students have different learning styles and preferences. Therefore, a more personalized approach that considers the individual needs and circumstances of students can be more effective in promoting their engagement and learning outcomes.

The study involved an embedded mixed-methods design, which integrates the collection in parallel of quantitative and qualitative data through the same survey instrument but giving more weight to the quantitative data and using the qualitative data to supplement the other part to explain and interpret them.

Since each institutional survey's platform allowed a different configuration of the surveys and generated an exported file with a different format, data homogenization was needed. This also included coding data for a smoother data analysis process.

Each country dataset was coded with two letters indicating the country and the answer's number. The whole dataset was coded based on legend codes, depending on the number of answers for multiple choices and single choice (1, 2, 3...), yes/no answers (1/0), and Likert scales (1-5). After this process, all the data were imported to the statistical software analysis.

Descriptive statistics were calculated based on frequencies, mean, median and asymmetry. These data were used to create different charts to visualize and interpret the findings.

Open-ended text answers were analyzed based on thematic analysis. Categories were inductively developed per each item according to the answers. Each category was divided into codes that included the different answers related to each topic. Also, frequencies per each category and code were calculated. The coding process included different phases of revision of the codes and quotes, involving different members of the team to ensure reliability of the final coding system.

3.3 OVERVIEW OF THE QUESTIONNAIRES

Table 3-1 Presents the data sets that were used in the analysis that is presented in the next Chapters of this document

Questionnaires	5-point liker scale questions	Open questions	Student/ Teacher participation in the project	# of student/ teacher answering to the questionaries
Multiplier Events	11	2	232	96
Teacher reports	6	10	232	133
Students pre	11	0	548	421 (matched)
Students post	25	0	528	421 (matched)

4

ASSESSESMENT OF THE IMPACT OF THE MULTIPLIER EVENTS

4 ASSESSESMENT OF THE IMPACT OF THE MULTIPLIER EVENTS

4.1 INTRODUCTION

The Multiplier Events are in essence visionary workshops designed to introduce teachers to the project approach. Their goal is to demonstrate the potential of Playing with Protons goes Digital for enhancing student learning science through AR resources developed by the project.

During the events, teachers engage in a productive dialogue about the proposed methodology and its feasibility and adaptation to local challenges and realities.

During the 12 Multiplier Events (few replicas included) teachers are encouraged and supported to create their AR scenario using the tool provided by the project (IO2 and IO3).

Multiplier Events are organized in 4 phases:

1. Introduction
2. Methodology
3. AR tool description
4. Laboratory

In the laboratory few examples, provided by the consortium, are tested with the teachers to show the potentiality of the tool and the possible implementations. Teachers are then invited to implement their own AR scenario and discuss with us how they propose it to the students.

In turn, the consortium provides continuous support and guidance throughout the pilots, by making training materials available online to facilitate teachers' work. The event takes a collaborative format, with teachers sharing their views and discussing what is being presented by colleagues, science educators, and others.

Due to the COVID-19 restrictions some of the teachers joined the Multipliers Events virtually.

Picture 4 1 Activities during Multiplier event in Spain.

Picture 4 2 Activities during the Multiplier Events in Spain

At the end of each Multiplier Event, teachers are invited to fill a questionnaire (Annex I) made of 12 questions to evaluate:

The 12 close-ended questions were rated on 5-point Likert-type scales (e.g., 1=extremely poor, to 5=excellent; 1=No, to 5=Yes).

The questionnaire also included the following two open-ended questions:

1. What future training needs do you expect to occur, which you would like to be addressed?
2. Do you have any suggestions for follow-up events or actions to set up?

Evaluation data were collected from a total of 232 teachers who took part in the 12 multiplier events and completed fully the questionnaire:

- N. 47 from Spain
- N. 104 from Italy
- N. 81 from Greece

Below is the description of the results obtained following the implementation of the Multiplier Events in the various partner countries.

The answers related to the question about the interest in the Playing with Protons goes Digital project show a very encouraging results (Figure 4 1 and Figure 4 2) with a mean value of about 94% (Figure 4 3) of the teacher that scored 4 or 5 to the interest in the methodology and the idea to recommend it to the colleagues.

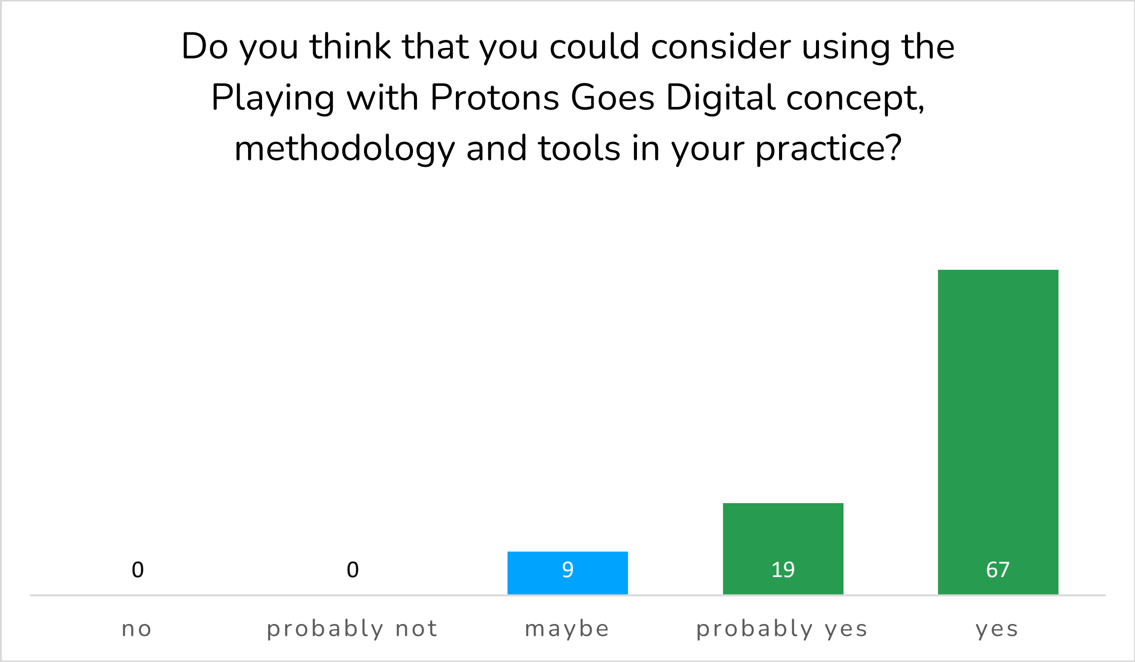


Figure 4-1 Score distribution about the possible usage of the methodology and tool at school.

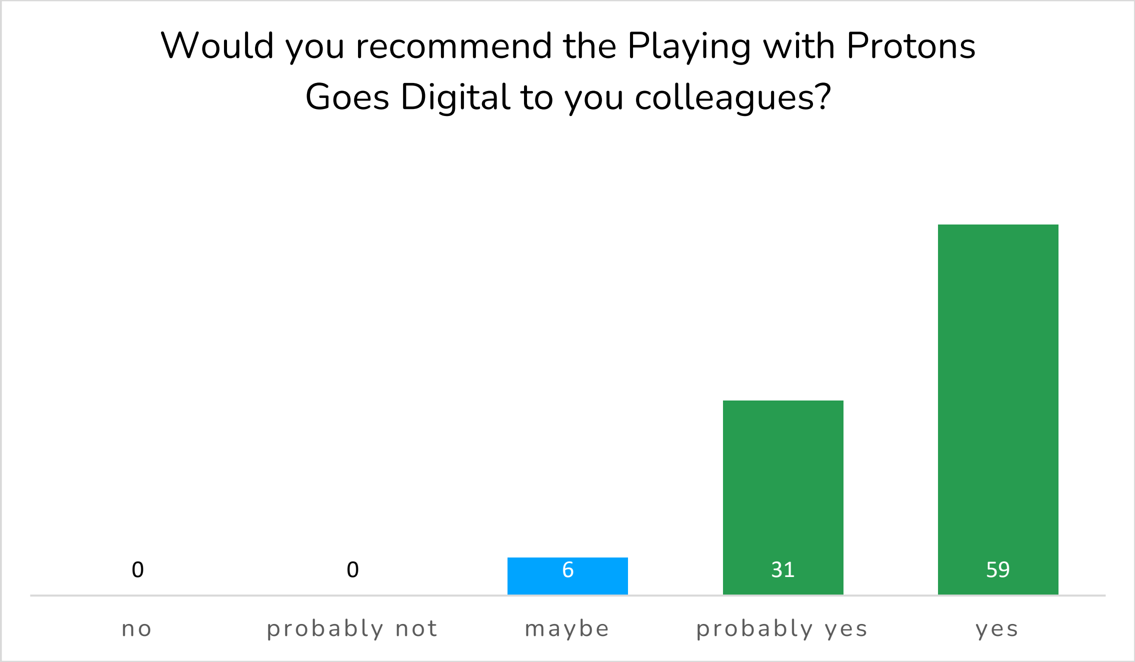


Figure 4-2 Score distribution of the possibility to recommend the Playing with Protons goes Digital project to the colleagues.

Table 4-1 Multiplier Events' evaluation summary table (mean value and standard deviation)

Question	Mean	Std Dev
To what extent did the content of the event address your expectations?	4.2	0.5
How satisfactory was the agenda of the event?	4.4	0.6
How would you rate the quality of the presentations?"	4.4	0.5
How would you rate the content of the presentations?	4.4	0.6
Was the content of the presentation helpful for increasing your level of awareness about the role of advanced digital technologies in supporting both traditional and remote STEAM teaching?	4.3	0.8
Were the speakers well prepared and engaging?	4.6	0.7
Was the location chosen for the event convenient?	4.6	0.6
How would you rate the overall organization of the event?	4.7	0.5
How would you rate the opportunities for networking during the event?	4.3	0.6
Do you think that you could consider using the Playing with Protons Goes Digital concept, methodology and tools in your practice?	4.1	0.9
Would you recommend the Playing with Protons Goes Digital to you colleagues?	4.2	0.9
To what extent did the content of the event address your expectations?	4.2	0.5

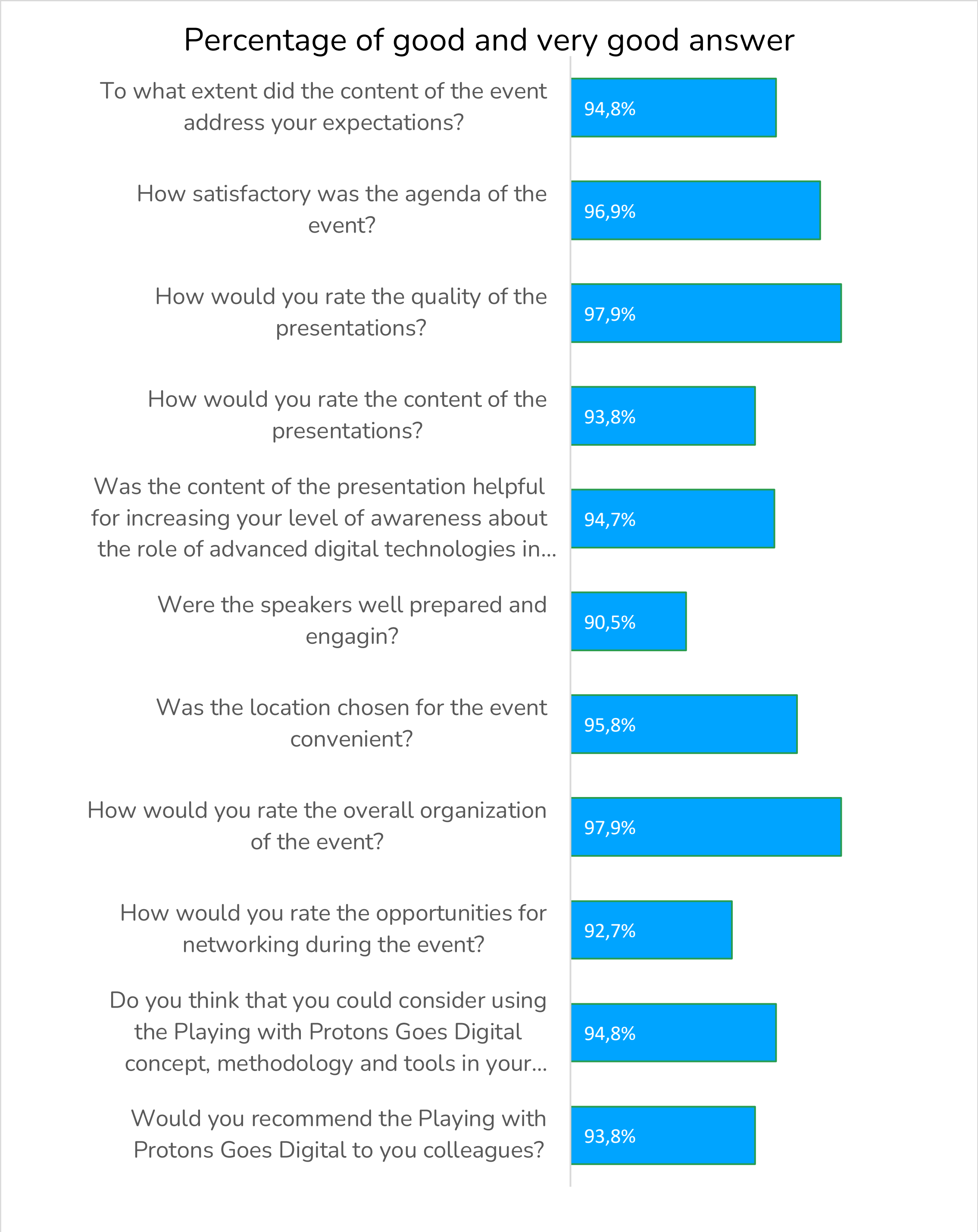


Figure 4-3 Percentage of good and very good answer per question.

4.2 TEACHER'S VIEW OF PLAYING WITH PROTONS GOES DIGITAL METHODOLOGY (MULTIPLIER EVENTS EVALUATION)

Teachers interested in Playing with Protons goes Digital project are teachers at primary and secondary school (students from 6 to 15 years old). In addition, the target group are children who are between 6-15 years old and are attending school. Before implementing the methodology and the AR scenarios in class teachers should become familiar with its technology and be well informed about the subject that they will teach. Teachers could use the material that is created during this project which contains information about science and inquired based learning for students. However, it is true that to implement an effective scenario the goals should be clearly defined. The correct identification of the objectives allows the educator to define and customize the training. In other words, the question that should be carefully considered is "What skills?". In addition, it is also recommended that the scenarios must be suitable for students based on their developmental identified needs and expected achievements. For this reason, teachers are also advised to creatively adapt this methodology into their own educational contexts. After a careful planning of the implementation teachers could conduct the classroom sessions. Regarding the AR session children should be led to use the AR equipment (mobile phone and tablet).

The goal is that learners are allowed to work autonomously and at their own pace. Teachers take the role of external observers allowing children to interact freely with the system which provides feedback and stimulates the child interaction. They should intervene only in case there will be arguments among the students or further explanations needed regarding the use of the portal. Afterwards, a discussion could take place in class based on the students' experiences and the goals of the session. Teachers also could use the PowerPoint Presentations and choose some of the hands-on activities.

131 of 232 teachers who took part in the multiplier events agreed to implement the Playing with Protons goes Digital methodology, AR tool and the scenarios in their classrooms. Other teachers, from the same schools, then joined the experimental phase.

An online questionnaire was developed and administered to the participating teachers immediately after the completion of the experimental phase at school. The questionnaire (available in Annex I) included 6 closed questions and 8 open questions, some of them including several items, on mainly pedagogical aspects of the educational virtual pathway, most of them being closed multiple-choice questions but also open-ended question, as well as background information. Specifically, respondents were asked to:

- Rate the Playing with Protons goes Digital concept, methodology and tools.
- Rate the scientific topics chosen for the AR scenarios.
- Judge the digital equipment present today in their school.

The teacher questionnaire has been submitted to all the 232 teachers from Italy and Greece at the end of the activities done with students. 131 teachers answered to it that corresponds to a very high fraction of respondents of 56%.

4.3 TEACHERS' PROFILE

Looking at the teachers' profile shown in we can state that about 83% of teachers participating to the AR activities in the classroom are female and 70% are from elementary schools where the students are 5-9 years old.

Participants were asked to rate on a 5-point Likert-type scale the relative usefulness of the training course they attended (1=very useless, to 5=very useful).

Table 4-2 Number of teachers participating to the different phases.

	Multiplier Event	Answered to the teacher questionnaire
# of Teachers	232	131

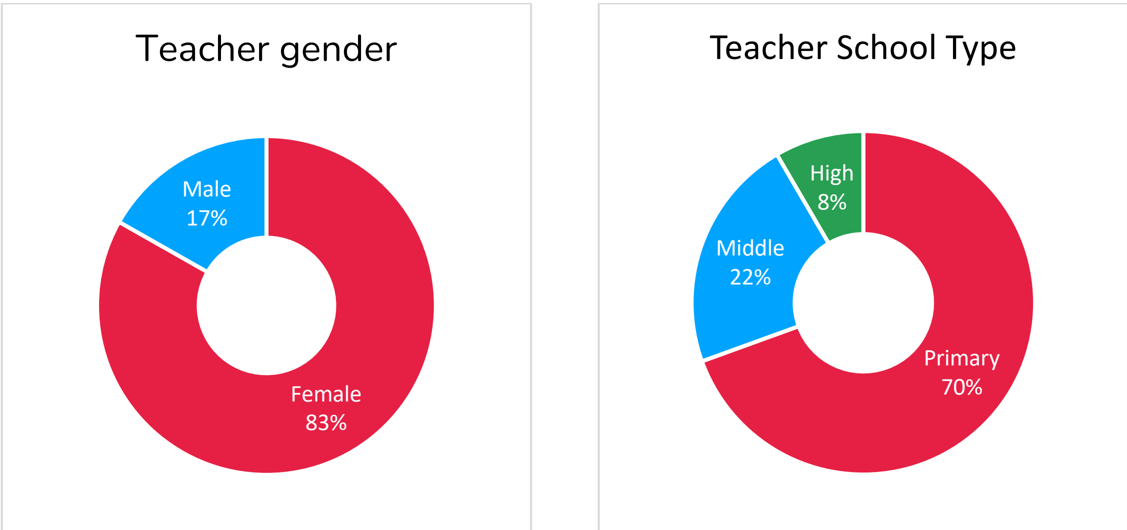


Figure 4-4 Teacher profile (gender and school type)

The collected data were analyzing looking at multiple statistical quantities.

For each of the six questions we analyzed the distribution on the scale 1-5 and measured the average value, the standard deviation, the asymmetry, and the median.

In the **Error! Reference source not found.** are reported the mean value and the standard deviation of each question.

A second analysis has been done grouping the two higher scores (4 and 5) and the two lower scores (1 and 2) to estimate a level of satisfaction for each question. The results are shown in Figure 4 8 in which the percentage of the three classes (positive, neutral, and negative) of satisfaction have been reported.

More than 70% of the teachers answered with a score of 4 or 5 to 5 of the 6 questions, showing very positive feedback to the Playing with Protons goes Digital project. The answers to the question regarding the school infrastructure support for the AR/VR activities like Playing with Protons goes Digital have shown Figure 4-5 a clear message about the necessity to support and improve the digital technologies of the participating schools. The mean value for this question is 3.35 clearly lower than the 4.0 of the other questions. About 16% of the teachers declared that the digital equipment of their school is very poor/poor and 41% answered with a neutral value (3) to this question.

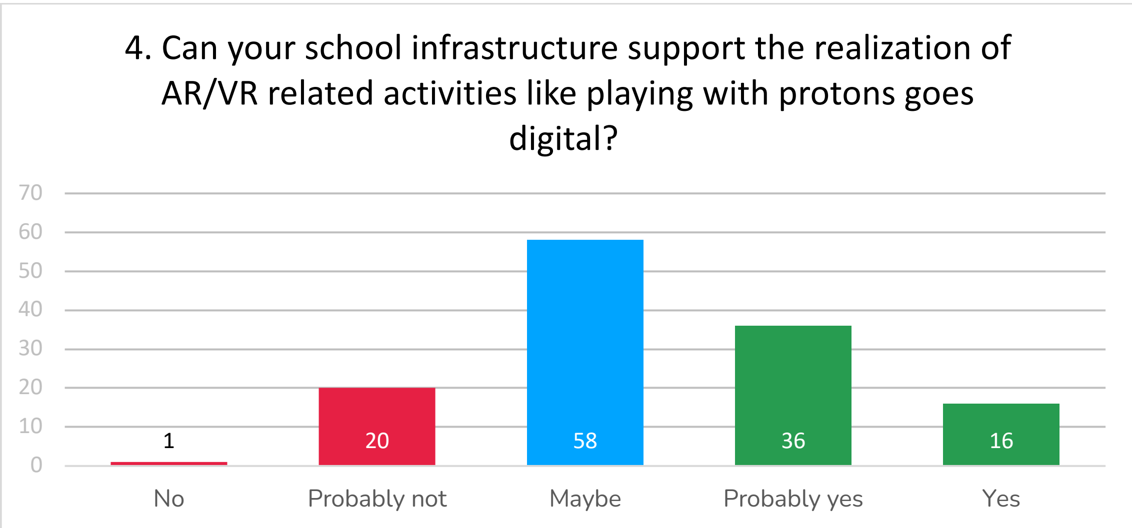


Figure 4-5 School digital infrastructure distribution

In Figure 4-6 and Figure 4-7 are shown the distribution of two questions strongly related to the level of satisfaction of the teachers. About 71% of the teachers scored very well the scenarios topics (see IO2 and IO3 document). The topics of the scenarios have been chosen to cover a wide range of scientific subjects that could affect both primary and secondary school students (from 5 to 15 years old).

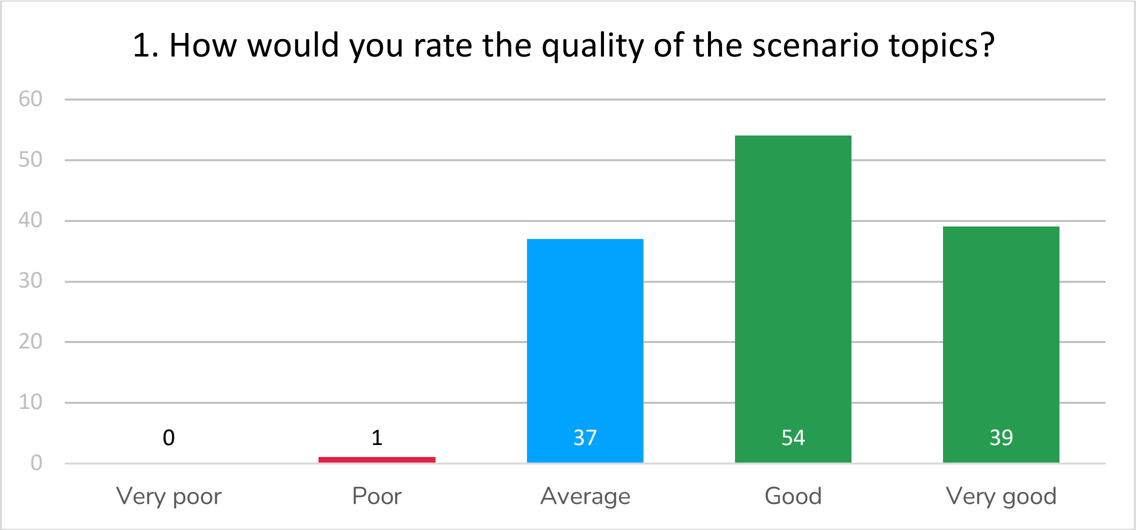


Figure 4-6 Question #1 distribution (5-points Likert scale)

Are about 75% (Figure 4-2 and Figure 4-8) of the teachers who would recommend to their colleagues to use during study both the scenarios and the other digital activities proposed by the Playing with Protons goes Digital project.

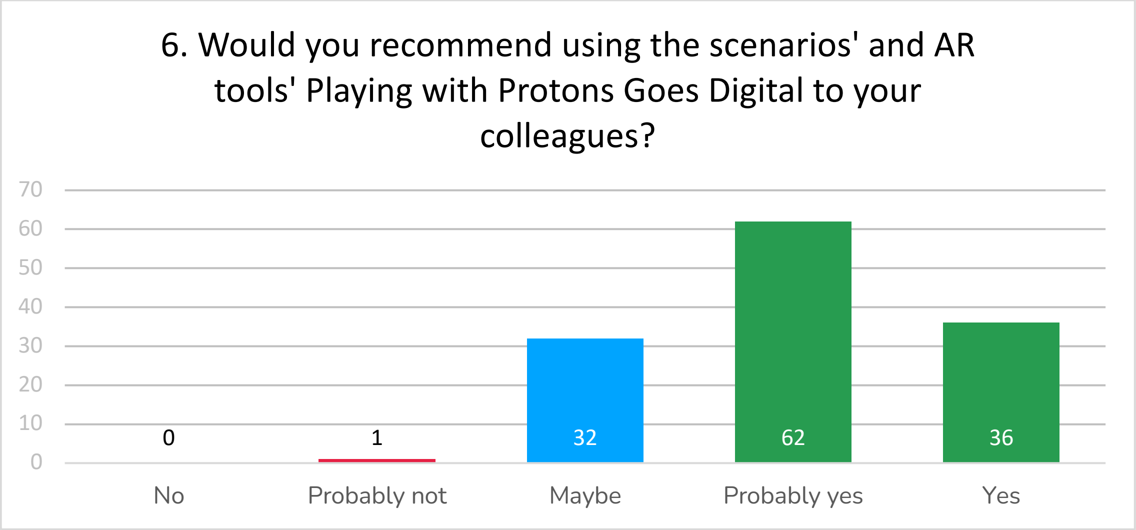


Figure 4-7 Question #2 distribution (5-points Likert scale)

In Figure 4-8 (Overall Satisfaction level) the results of the six questions are shown, having grouped them into 3 groups (positive, neutral, negative). They are all above the 70% of positive answers but the one regarding the school infrastructure that is around the 40%.

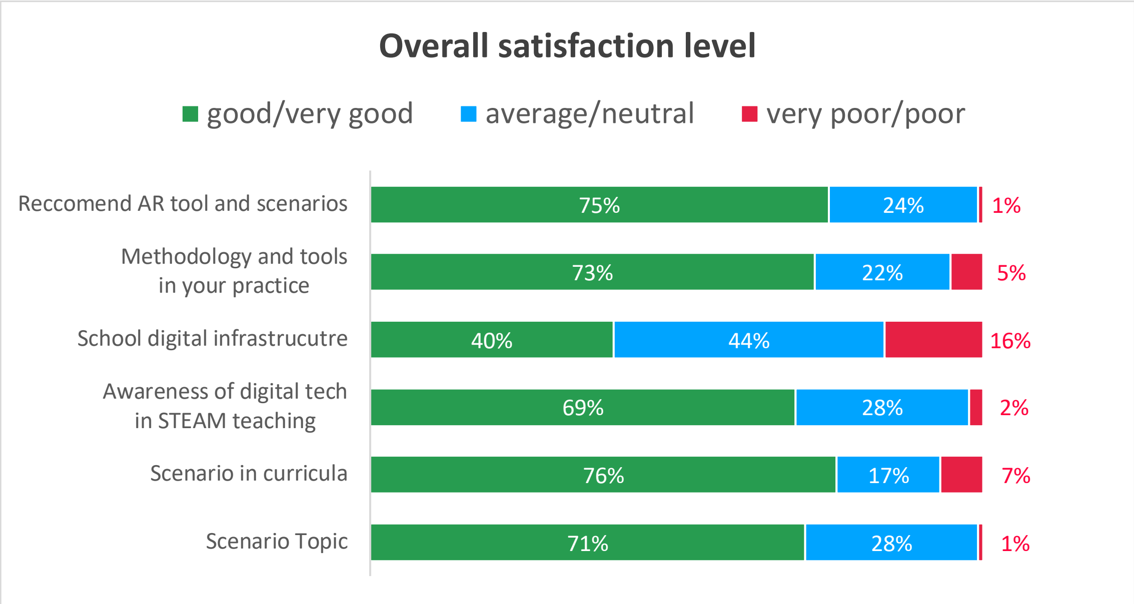


Figure 4-8 Merged (1-2 and 4-5) percentage of answers.

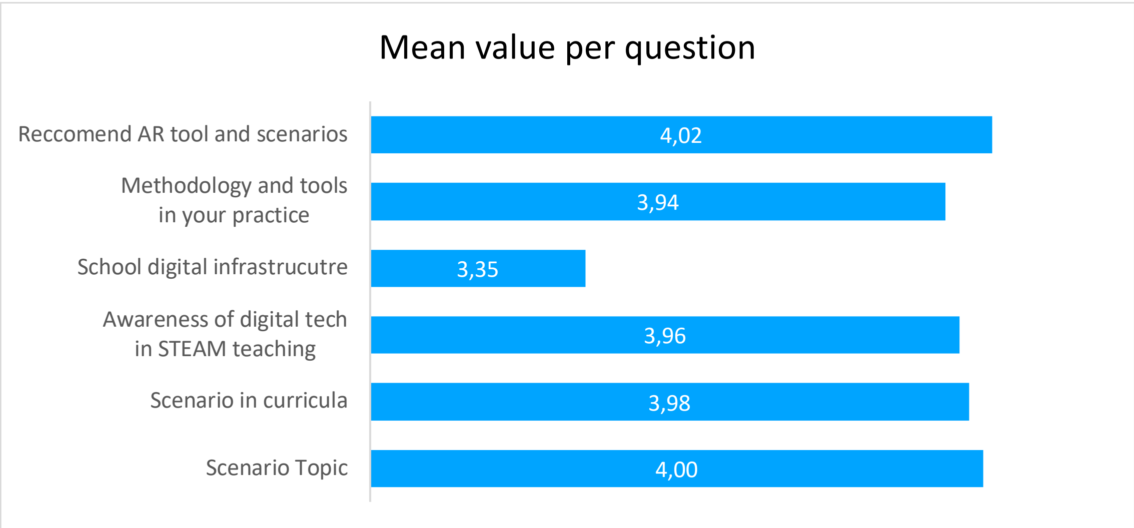


Figure 4-9 The mean value of each question is plotted.

Table 4-3 Mean values and standard deviation of the six teacher questions.

Question	Mean	Std Dev
1. How would you rate the quality of the scenario topics?	4,00	0,78
2. How would you rate the usefulness of the scenarios into curricular activities?	3,98	0,83
3. Was the activity helpful for increasing your level of awareness about the role of advanced digital technologies in supporting STEAM teaching?	3,96	0,84
4. Can your school infrastructure support the realization of AR/VR related activities like Playing with Protons Goes Digital?	3,35	0,91
5. Do you think that you could consider using the Playing with Protons Goes Digital concept, methodology and tools in your practice?	3,94	0,84
6. Would you recommend using the scenarios' and AR tools' Playing with Protons Goes Digital to your colleagues?	4,02	0,74

Finally, we merged the answers 1-2-3-5-6 (Figure 4 10) in one to measure a global level of satisfaction of the proposed project (Table 4 3). The mean value of the distribution shown in Figure 4 10 is 3,98 with a standard deviation of 0,81.

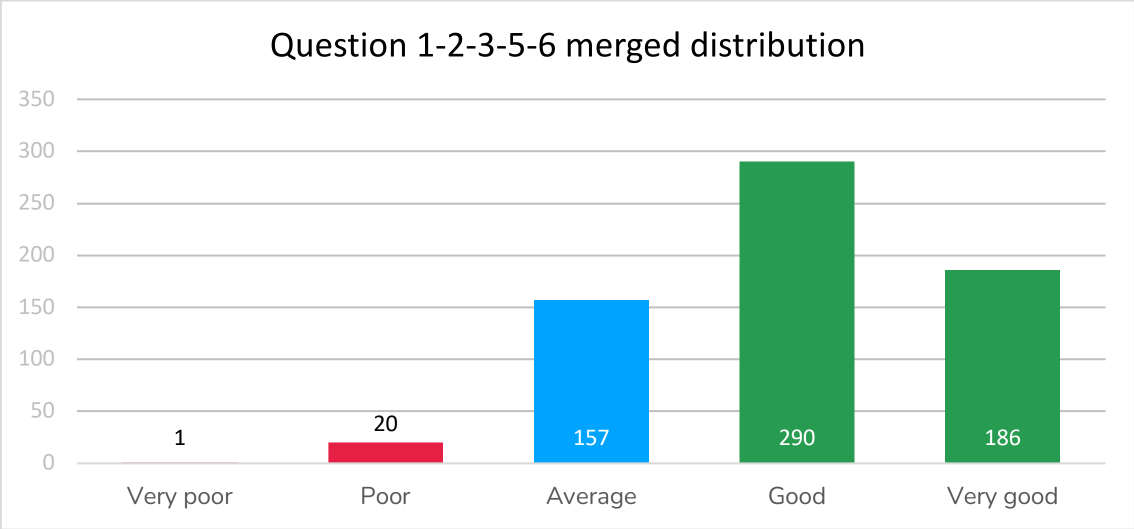


Figure 4-10 Distribution of the merged questions 1-2-3-5-6.

4.4 CONCLUSION

In overall teachers have found the project and the activities carried out very useful to improve their scientific knowledge and to offer students new digital applications such as augmented reality.

The majority of the teachers (71%) felt that the topics of the scenario were very interesting and useful and that can be easily incorporated into the curriculum (76%).

More than 70% of the teachers claimed to want to use the Playing with Protons Goes Digital concept, methodology and tools at school and that would recommend using the scenarios' and AR tools' Playing with Protons Goes Digital to their colleagues.

Only 1 teacher out of 131 would not probably recommend it.

5

IMPACT ON STUDENTS INTEREST AND MOTIVATION

5 IMPACT ON STUDENTS INTEREST AND MOTIVATION

5.1 INTRODUCTION

Primary and secondary school students, together with teachers and educators, represent the final beneficiaries of the educational interventions implemented in the context of Playing with Protons goes Digital.

5.2 METHODOLOGY

Table 5-1 Information about the steps of the methodology

Survey Date	Initial/Final Student Sample
Jan-Nov 2023	648 students from 40 schools participating. 421 students from 40 schools made pre-post.
Data collection	Data Analysis
Online survey	Quantitative analysis Pre-post comparisons. Analysis of semi-structured text data

Description of motivation, emotion, and cognitive load measures: SMQ Science Motivation Questionnaire.

In general, motivation is the internal state that arouses, directs, and sustains goal-oriented behaviour (Glynn, 2011). Motivation to learn refers to the disposition of students to find academic activities relevant and worthwhile and to try to derive the intended benefits from them (Brophy, 2004). In studying the motivation to learn science, researchers examine why students strive to learn science, how intensively they strive, and what beliefs, feelings, and emotions characterize them in this process.

In the social-cognitive theory of human learning (Bandura, 2001, 2005, 2006), students' characteristics, behaviours, and learning environments are viewed interactively. Within this theoretical framework, learning is most effective when it is self-regulated, which occurs when students understand, monitor, and control their cognition, motivation, and behaviour (Schunk, 2001; Schunk & Pajares, 2001). Motivated students achieve academically by strategically engaging in behaviors such as class attendance, class participation, question asking, advice seeking, studying, and participating in study groups (Pajares, 2001, 2002; Pajares & Schunk, 2001). First, there is intrinsic motivation, which involves learning science for its own sake (e.g., Eccles, Simpkins, & Davis-Kean, 2006). There is extrinsic motivation, which involves learning science to an end (e.g., Mazlo et al., 2002).

Third, there is personal relevance, which is the relevance of learning science to students' goals (e.g.,Cavallo et al., 2003). Fourth, there is self-determination, which refers to the control students believe they have over their learning of science (e.g., Black&Deci, 2000). Fifth, there is self-efficacy, which refers to students' confidence that they can achieve well in science (e.g., Lawson, Banks, & Logvin, 2007). And sixth, there is assessment anxiety, which is the debilitating tension some students experience in association with grading in science (e.g., Parker & Rennie, 1998).

A construct, such as motivation to learn science, is not a directly observable variable. For this reason, a construct is often called a latent variable. Although a construct cannot be directly observed, it can be measured by means of items that serve as empirical indicators of how the construct is conceptualized by students. A construct could be conceptualized by students either as a unitary entity or as one with dimensions (sub-constructs). Students' conceptualizations of a construct may differ somewhat from how experts conceptualize it and describe it in the literature (Donald, 1993). Students' conceptualizations are important, however, particularly within a social-constructivist view of learning science, because students' conceptualizations influence their actions (McGinnis et al., 2002; Scott, Asoko, & Leach, 2007).

The Science Motivation Questionnaire II (Glynn) consisted of the following five subscales/factors, indicating that they were related to the six motivational components that influence self-regulated learning. Factor 1: intrinsic motivation; Factor 2: self-efficacy; Factor 3: self-determination; Factor 4: career motivation; Factor 5: grade motivation (each 5 items).

The students found science intrinsically motivating (interesting, enjoyable, etc.) when it was personally relevant (valuable, important, etc.) and vice versa. When the students had high self-efficacy (I am confident, I believe I can, etc.), they were not anxious about assessment (I am nervous, I worry, etc.), and this was evident in their explanations of their motivation to learn science.

Glynn found no significant differences in total scores on the Science Motivation Questionnaire due to gender; however, there were small, meaningful score differences on the factor-based scales, which indicated that different profiles of motivation to learn science were associated with gender. The scores on the self-efficacy and assessment anxiety scale were higher among the men then the women, suggesting that the men had more confidence and less anxiety than the women did.

For our young participants we must consider which sub-scales of the SMQII are focused. Originally the SMQ was designed for university freshmen (Glynn, 2011). Marth & Bogner (2017) have inserted this instrument in the transition passage from primary to secondary school students. Finally, the questionnaire could be inserted in all age groups and show good results.

The SMQ II survey may deal with following questions:

- Do specific Playing with Protons goes Digital activities influence the students' science motivation?
- Could the motivation to learn science be raised?
- Are there gender differences?

The Intrinsic Motivation Inventory (IMI) is a multidimensional measurement device intended to assess participants' subjective experience related to a target activity in laboratory experiments.

It has been used in several experiments related to intrinsic motivation and self-regulation (e.g., Ryan, 1982; Ryan, Mims & Koestner, 1983; Plant & Ryan, 1985; Ryan, Connell, & Plant, 1990; Ryan, Koestner & Deci, 1991; Deci, Eghrari, Patrick, & Leone, 1994). The instrument assesses participants' interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice while performing a given activity, thus yielding six subscale scores.

The interest/enjoyment subscale is considered the self-report measure of intrinsic motivation; thus, although the overall questionnaire is called the Intrinsic Motivation Inventory, it is only the one subscale that assesses intrinsic motivation, per se. As a result, the interest/enjoyment subscale often has more items on it that do the other subscales. The perceived choice and perceived competence concepts are theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation, and pressure/tension is theorized to be a negative predictor of intrinsic motivation. Effort is a separate variable that is relevant to some motivation questions, so is used it its relevant. The value/usefulness subscale is used in internalization studies (e.g., Deci et al, 1994), the idea being that people internalize and become self-regulating with respect to activities that they experience as useful or valuable for themselves.

The IMI items have often been modified slightly to fit specific activities. Thus, for example, an item such as "I tried very hard to do well at this activity" can be changed to "I tried very hard to do well on these puzzles" or "...in learning this material" without effecting its reliability or validity. As one can readily tell, there is nothing subtle about these items; they are quite face valid. However, in part, because of their straightforward nature, caution is needed in interpretation.

Another issue is that of redundancy. Items within the subscales overlap considerably, although randomizing their presentation makes this less salient to most participants. Nonetheless, shorter versions have been used and been found to be quite reliable. Still, it is very important to recognize that multiple item subscales consistently outperform single items for obvious reasons, and they have better external validity.

We recommend a shortened standard version with the four subscales: interest, perceived competence, perceived choice, and pressure/tension with 4 items per subscale.

The state emotions survey may deal with following questions:

- Do specific Playing with Protons goes Digital activities influence the students' general motivation?
- Are there gender differences?

The Situational Emotions Questionnaire (State Emotions) measures the learning emotions after an intervention with three concepts: interest, well-being, and boredom. Each subscale has three items and is to be used complete.

The Situational Emotions may deal with the following questions:

- What emotions have students at Playing with Protons goes Digital activities?
- Are there gender differences?

A scale from 1 (not at all true) to 5 (very true) is used.

The Cognitive Load rating scale measures students' perceived difficulty. Students must report the amount of mental effort they invested in the intervention. Therefore, they are asked to estimate their perceived difficulty of the individual items immediately after they had finished an item. The rating scale must be provided, explained, and illustrated just before the beginning of the Playing with Protons goes Digital implementation. Students take the rating scale during the general instruction with them. After solving a problem or studying a worked-out problem the students had to score the amount of mental effort invested in the preceding problem.

To test the cognitive load without extra tension students must not be graded during the implementation.

The scale must be individually modified for the project partner's specific intervention.

The Cognitive Load survey may deal with following questions:

- Do specific Playing with Protons goes Digital activities influence the students' cognitive load?
- Does mental effort influence students' motivation (SMQII)?
- Are there gender differences?

5.3 STUDENT PROFILE

The sample of students answering to the pre, and post questionaries is made by 421 students from 29 schools, where 50% of the schools are from rural areas. About 88% of the students are between 9-11 years old and 55% are female.

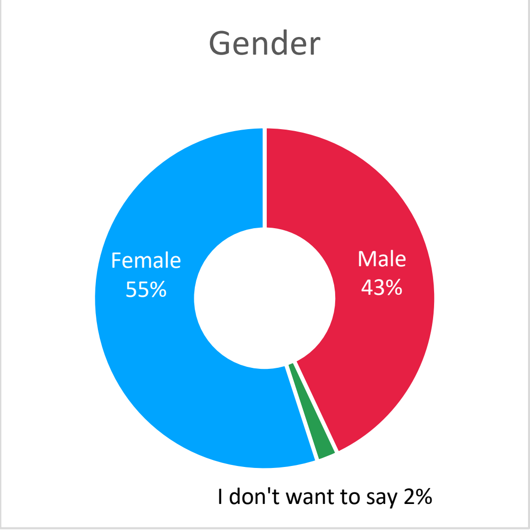


Figure 5-1 Gender distribution of the students

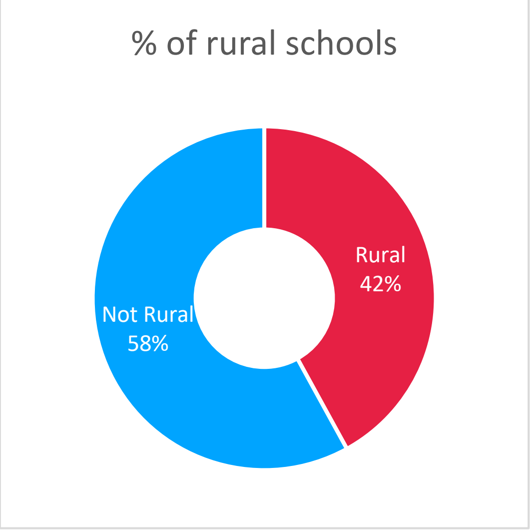
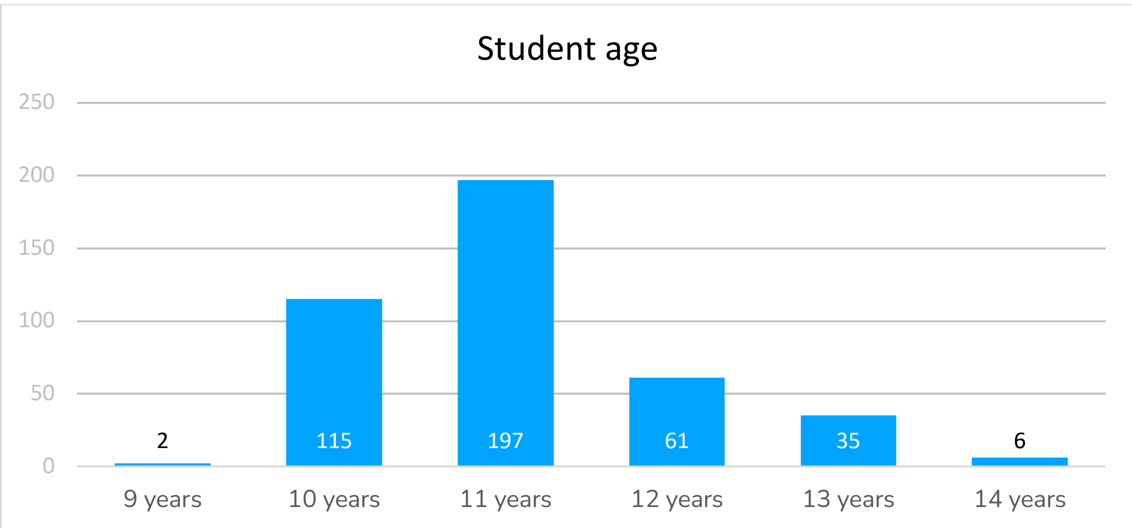


Figure 5-2 Percentage of rural schools

Table 5-2 Scholastic origin of the students

Type of school	# of students
Primary	363
Middle	54
High school	4
TOTAL	421
Rural	175
not Rural	246
TOTAL	421



- *Figure 5-3 Student age distribution*

5.5 ANALYSIS OF THE RESULTS

On average all students' post responses **Error! Reference source not found.** show a significant increase in their average value and this from a clear message about the effect generated by the Playing with Protons goes Digital project on the perception of science in the students involved.

Table 5-3 SMQII average value comparison per question.

Questions	Mean value - pre	Mean value - post
1. Learning science is interesting.	3.5	3.9
2. The science I learn is relevant to my life.	2.9	3.2
3. The science I learn is relevant to my life.	3.5	3.7
4. Learning science will help me identify the best course of study for my future.	3.0	3.3
5. Understanding science will benefit me in my studies.	3.1	3.4
6. I will use science problem-solving skills in my studies.	3.1	3.3
7. The choice of future studies will concern science.	2.9	3.1
8. I spend a lot of time learning science.	2.7	3.1
9. I believe I can earn a good grade in science.	3.5	3.8
10. I believe I can master science knowledge and skills.	3.3	3.6
11. Getting a good science grade is important to me.	3.7	3.8

Comparing pre and the post answer the first question “Learning science is interesting” the number of students that agree on this statement increased from 53% to 70% and in the meanwhile the number of students neutral remain constant. Performing a T-test ($P<0.05$) on the answer to the question #1 we reject the null hypothesis ($t \ll P$) and we can state that the two mean value obtained are statistically different.

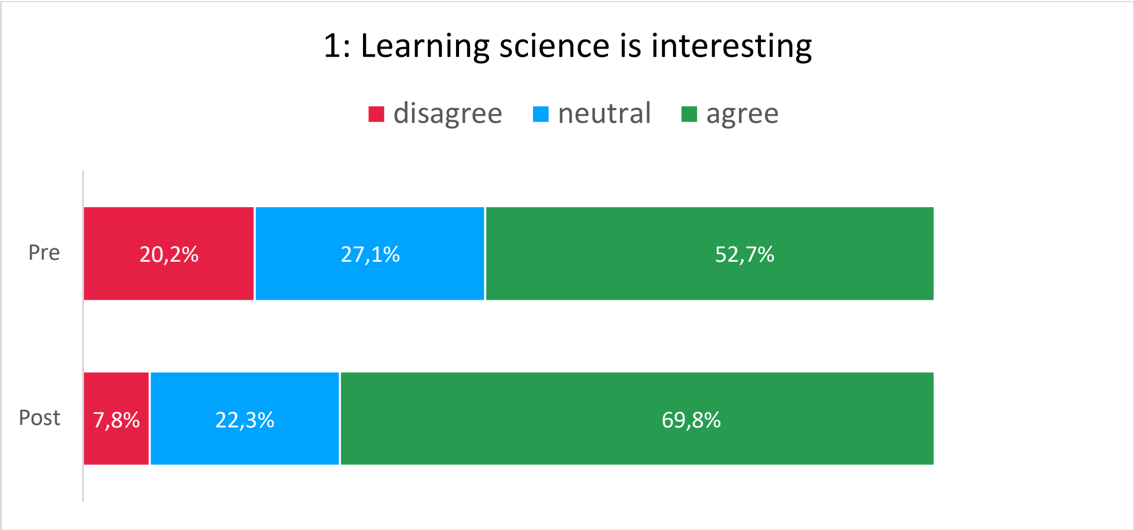


Figure 5-4 Percentage of score 1-2, 3 and 4-5 pre and post.

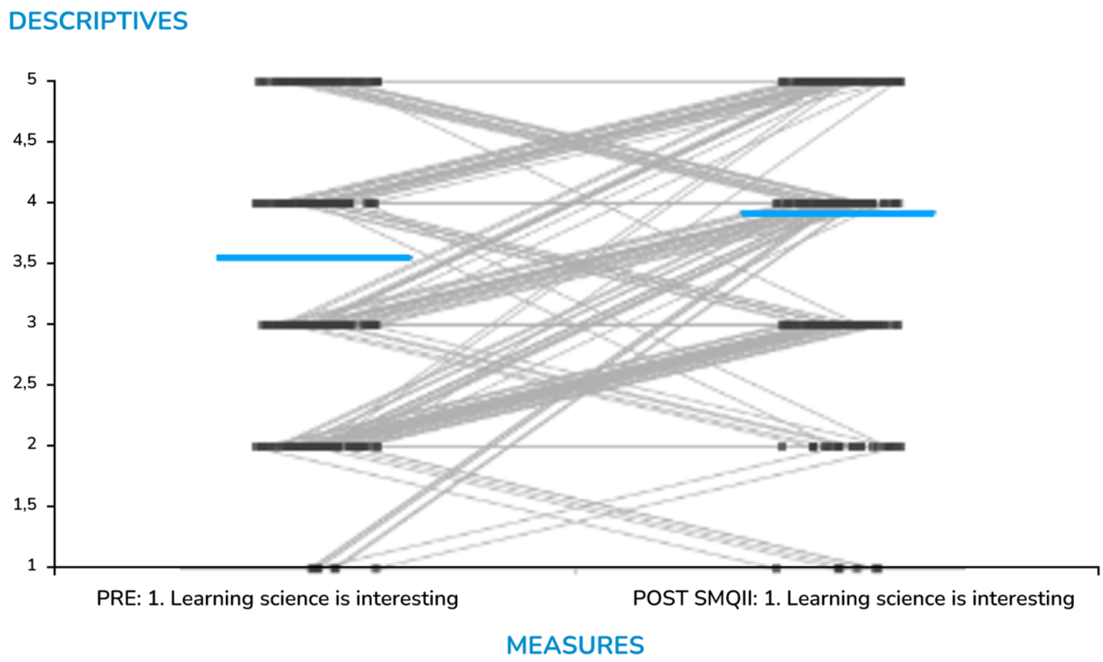


Figure 5-5 Comparing pre and post SMQII questionnaires at the question "Learning science is interesting".

Questions	N	Means	Means SE	SD
PRE: 1. Learning science is interesting	421	3.5	0,05	1,1
POST SMQII: 1. Learning science is interesting	421	3.9	0,05	1,0

A similar increase is also found for questions 3 (**Error! Reference source not found.**) and 10 (**Error! Reference source not found.**) from which we find a positive effect on students of the approach to science that we proposed. The number of students that agree on the statement "I enjoy learning science" increase from 50% to 62% and at the same time the percentage of neutrals remains constant around 25%.

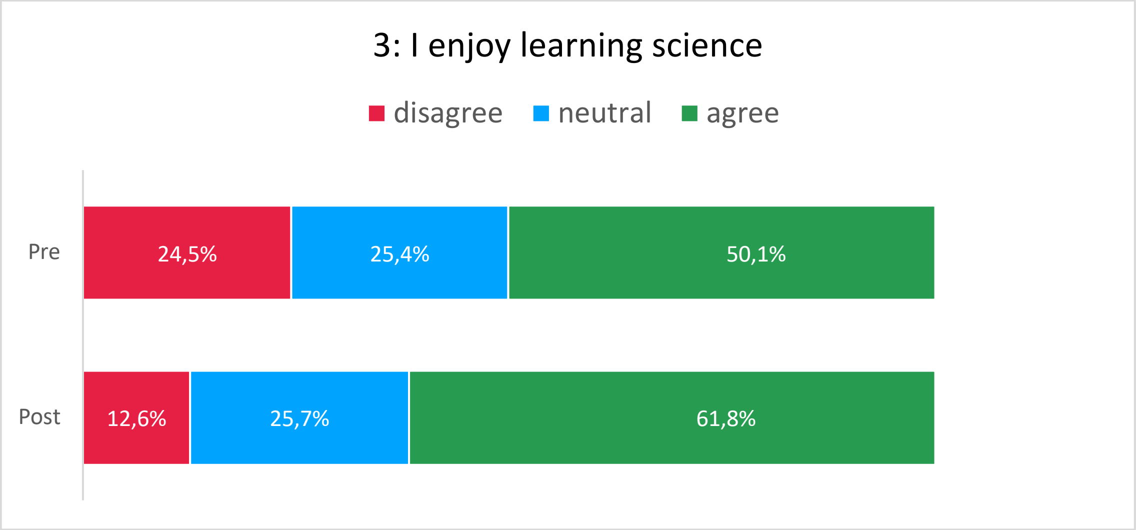


Figure 5-6 Percentage of score 1-2, 3 and 4-5 pre and post.

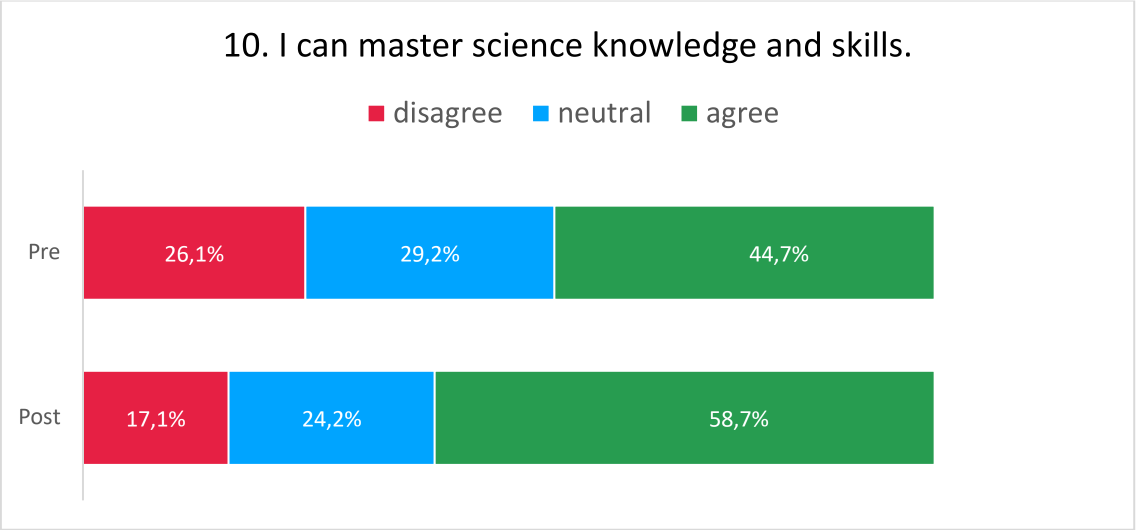


Figure 5-7 Percentage of score 1-2, 3 and 4-5 pre and post.

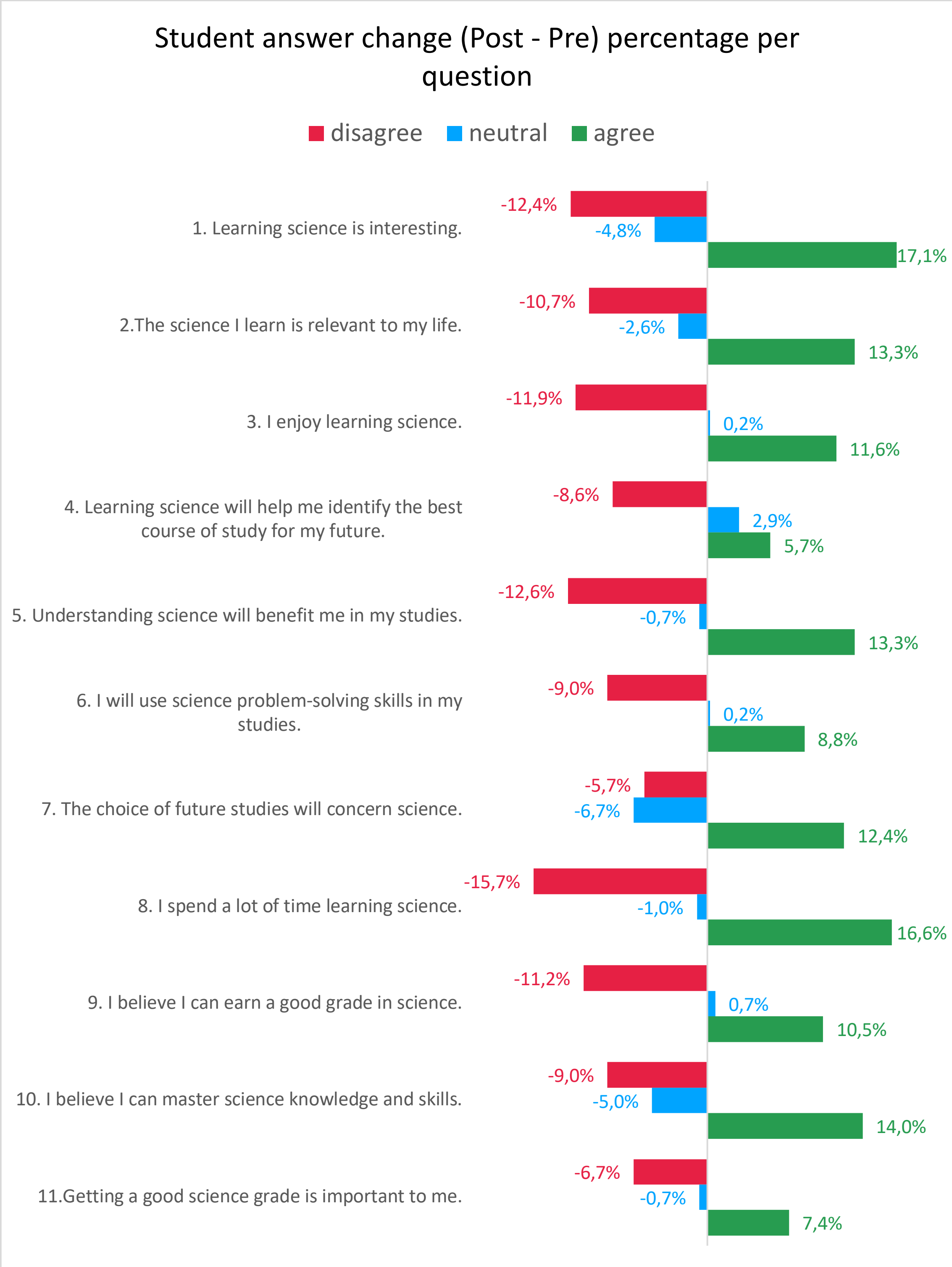


Figure 5-8 Pre-Post percentage change per question.

In addition to SMQII, we then analyzed the results obtained with the IMI questionnaire (see Table 5 4). To assess the students' interest in the activities carried out with the augmented reality tool and with the scenarios that we proposed we put together the answers to the first three questions (full distribution in Figure 5 9 and Figure 5 10) and obtained that the 58% of the students faced a lot positively this activity (see Figure 5 11).

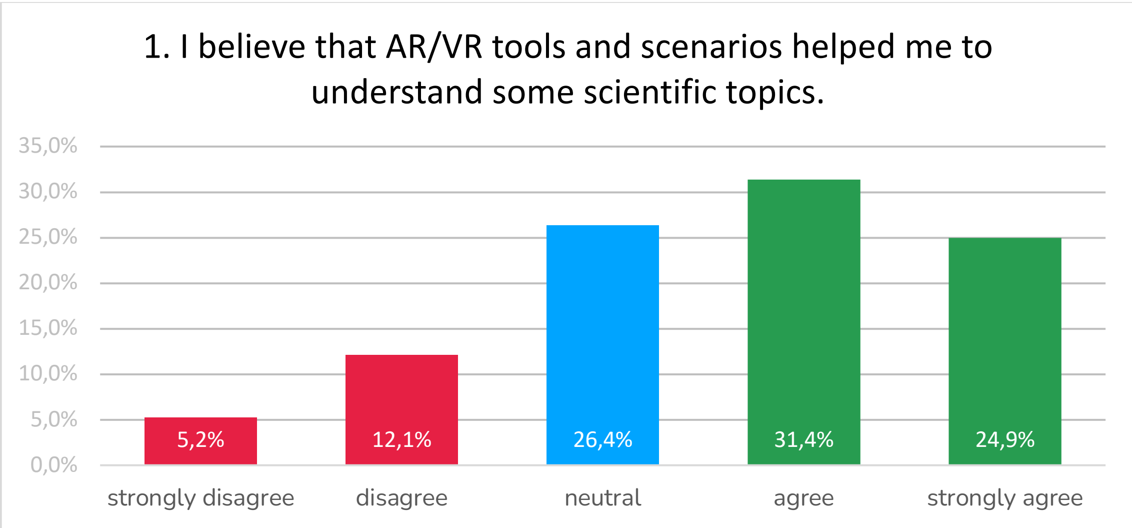


Figure 5-9 IMI question #1 distribution

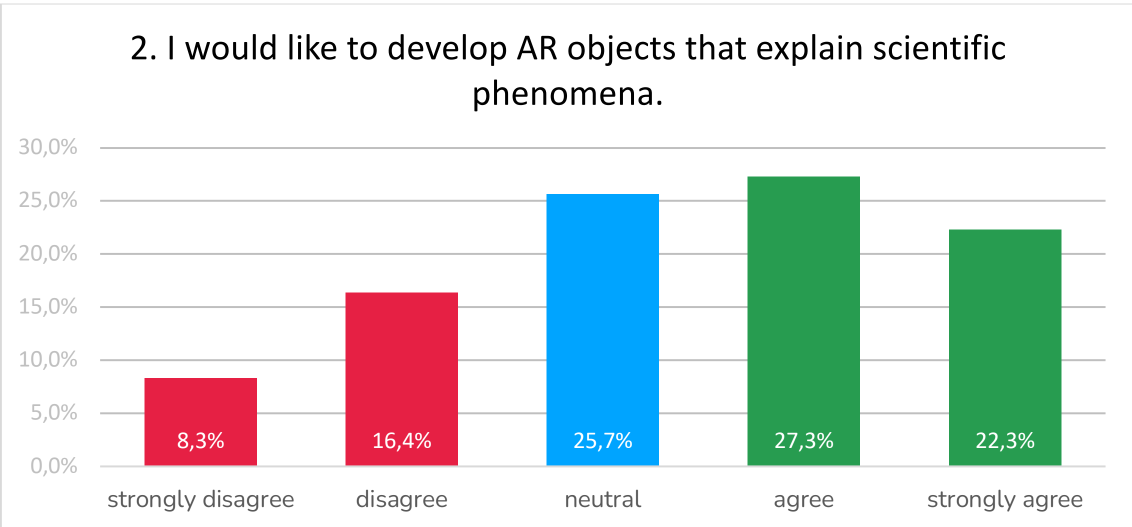


Figure 5-10 IMI question #2 distribution

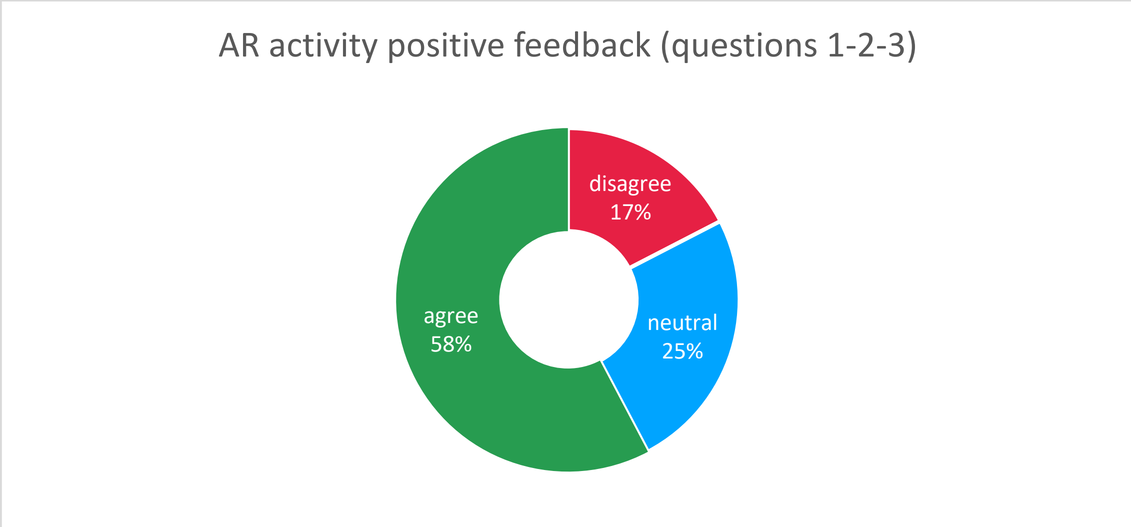


Figure 5-11 Pre-Post percentage change per question for the first three questions

A further positive message is obtained from the answers to question 6 which states "I would describe this activity as very interesting". Only 12% of students (see **Error! Reference source not found.**) claim to be in deep disagreement or disagreement with this statement.

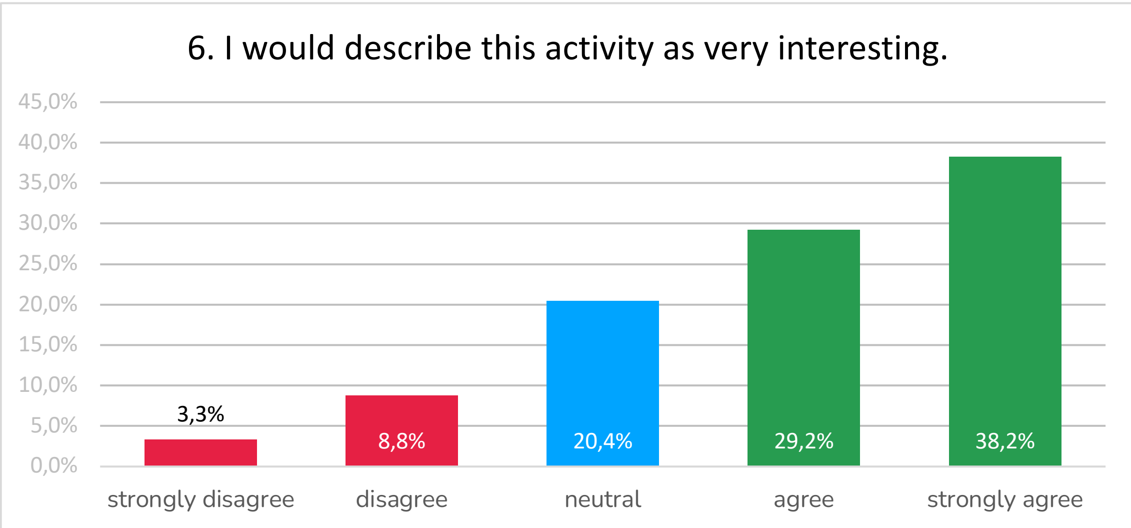


Figure 5-12 Pre-Post percentage change per question

Table 5-4 IMI percentage of answer per category (disagree, neutral, agree)

Question	Disagree	Neutral	Agree
1. I believe that AR/VR tools and scenarios helped me to understand some scientific topics.	17%	26%	56%
2. I would like to develop AR objects that explain scientific phenomena.	25%	26%	50%
3. I enjoyed doing this activity very much.	10%	23%	67%
4. I thought this was a boring activity.	64%	17%	19%
5. This activity did not hold my attention at all.	50%	29%	21%
6. I would describe this activity as very interesting.	12%	20%	67%
7. After working at this activity for a while, I felt competent.	18%	24%	58%
8. I am satisfied with my performance at this task.	10%	21%	69%
9. I was skilled at this activity.	16%	31%	53%
10. This was an activity that I couldn't do very well.	48%	27%	25%
11. I was anxious while working on this task.	64%	18%	18%
12. I felt pressured while doing this activity.	64%	18%	18%
13. I felt like I had to do this.	61%	16%	23%
14. I did this activity because I had no choice.	59%	19%	23%

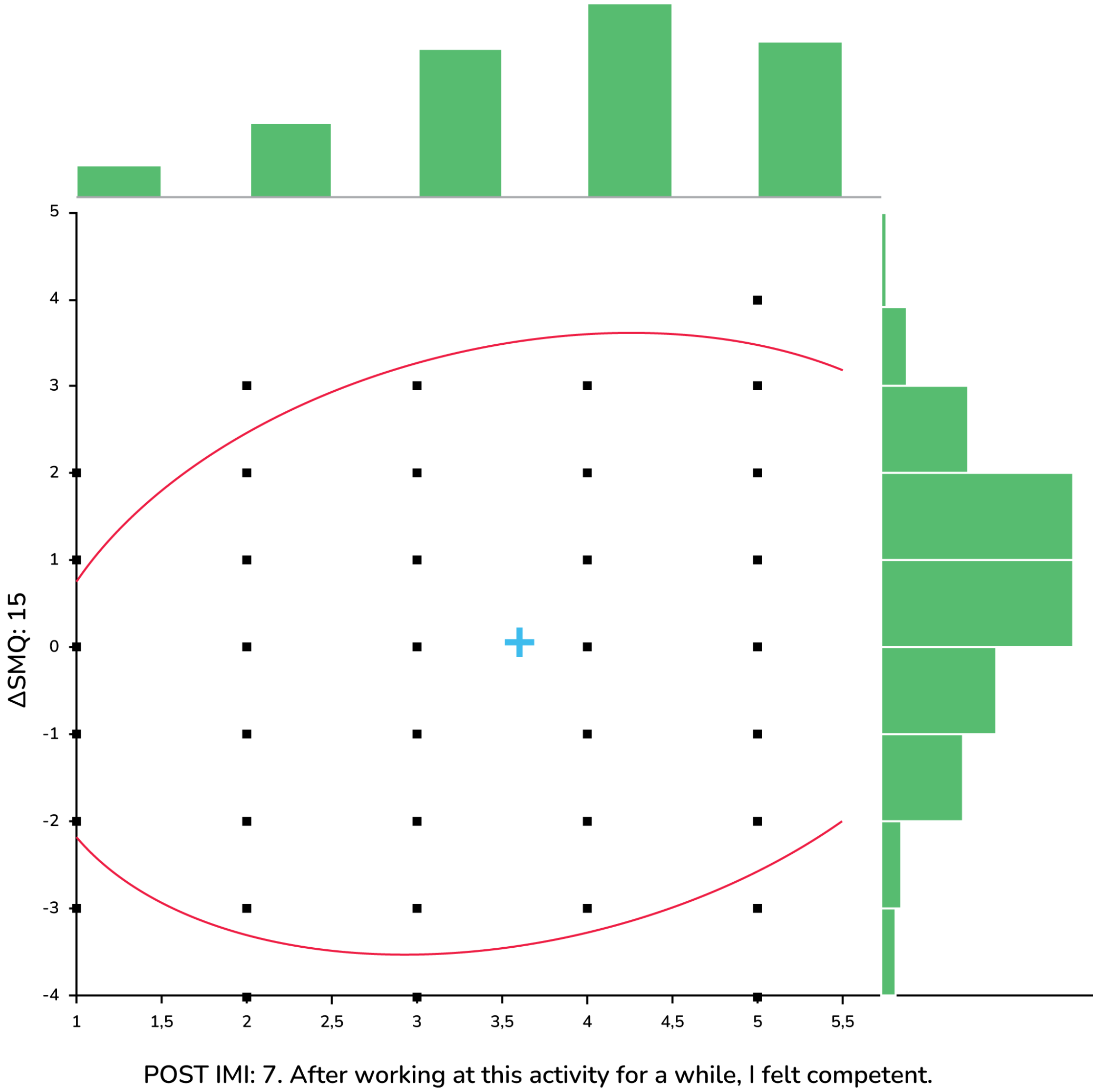


Figure 5-13 Correlation Matrix between Interest (SMQ values) and Competence in the use of AR (IMI)

CORRELATION		N 421
	POST IMI: 7. After working at this activity for a while, I felt competent.	ΔSMQ: 15
For a while, I felt competent		0,221 Pearson's r 0,181 Spearman's rs 0,145 Kendall's tau
ΔSMQ: 15	0,221 0,181 0,145	

Figure 5-14 Correlation between Interest (SMQ values) and Competence in the use of AR (IMI)

Finally, correlations between the SMQ and IMI (**Error! Reference source not found.**) responses demonstrate that there is a positive correlation between the increase of students' interest and the development of the students' competences in users of the AR authoring platform. This is a very interesting finding that demonstrates the overall impact of the project to students' skills in using advanced tools to describe complex phenomena.

6

CONCLUSION

6 CONCLUSION

In this final section, we provide a summary of what we consider the key findings presented in the previous sections. Based on these findings, we also attempt to highlight some lessons learnt based on which a set of recommendations for further exploiting the project' outcomes in multiple countries across Europe.

Key Findings — The scenarios and AR tools developed creates significant teaching and learning value for both teachers and students.

Teachers

- 73% of teachers considered using The Playing with Protons goes Digital methodology and tools in their practice.
- 75% teachers found AR tools and Scenarios as an effective tool also for supporting the development of transversal competencies.
- 76% teachers found AR tools and Scenarios helpful in making their teaching more innovative, motivating, and engaging.
- 75% of teachers would recommend AR tools and Scenarios to their colleagues.
- Most teachers described Playing with Protons goes Digital activities as a cost-effective digital tool for teaching science that compares better to other available tools.

Students

- Quantitative and qualitative evidence from more than 600 students aged 9-14 suggests that use of AR tools and the Scenarios increase knowledge scientific by improving their understanding of complex scientific concepts.
- Same evidence shows a significant and positive effect on student intrinsic motivation and interest in science.

- AR tools and scenarios, as perceived by teachers, has a notable equity component by offering authentic and engaging science learning activities to students in remote and rural schools that would otherwise be difficult for them to experience due to geographical and socioeconomic factors.

Although the evaluation concerned different educational interventions in different countries with different curricula, the underlying concept, structure, and methodology of those interventions are common. Therefore, it may be feasible to identify common pros and cons, based on which a preliminary list of lessons learnt is to be formulated. More specifically:

Common pros

- The Scenarios solution may be an effective tool for supporting the development of transversal competencies.
- Certain digitally enhanced activities, such as the AR tools, were considered valuable teaching resources, superior to other digital educational tools, and efficient in demonstrating the utility of ICT in teaching.
- The Multiplier Events were greatly appreciated by teachers, who found the hands-on approach and the opportunity to test the proposed scenarios for themselves extremely useful in their teaching activities.

Common cons

- Some teachers expressed the need for additional training due to a lack of basic ICT skills.
- The scenarios solution was not particularly effective in increasing science career motivation, likely due to the brief intervention duration.
- Most of the schools need improvements in the digital infrastructure.

Some information learnt.

- Incorporating digital tools and resources, such as AR tools, into classroom instruction can be a viable and effective approach to enhancing the quality of science education.
- Additional training and evaluations may be needed in areas such as ICT competence and multiliteracy to improve feedback. The scenarios and AR tools can provide valuable science learning experiences for all students, irrespective of their socioeconomic status.
- The hands-on approach, practical nature, and timing of training sessions can greatly impact their success, allowing teachers to participate without affecting their regular teaching schedule.
- Quality informal science learning experiences can significantly impact students' science intrinsic motivation, interest in informal science learning experiences.

7

REFERENCES

7 REFERENCES

- Dünser, A., & Hornecker, E. (2007). An observational study of children interacting with an augmented story book.
- Proceedings of 2nd International Conference of E-Learning and Games (Edutainment 2007), CUHK, Hong Kong. pp. 305-315.
- Kondo, T. (2006). Augmented Learning Environment using Mixed Reality. Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2006. Honolulu, Hawaii, USA, pp. 83-87.
- Liu, W., Cheok, A. D., M-L, C.L., Theng, Y-L. (2007). Mixed Reality Classroom: Learning from Entertainment. Proceedings of the 2nd international conference on Digital Interactive Media in Entertainment and Arts. Perth, Australia, pp. 65-72.
- Malone, T.W. & Lepper, M.R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow & M. J. Farr (Eds.).
- Aptitude, Learning, and Instruction, Vol 3. Cognitive and affective process analyses (pp. 223-253). Hillsdale, NJ: Lawrence Erlbaum.
- Bandura, A. (1986). Social foundations of thought and action: A social cognitive Theory. Englewood Cliffs, NJ: Prentice Hall. Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. Child Development, 72, 187-206. doi: 10.1111/1467- 8624.00273
- Bellebaum, A. (1990). Langeweile, Überdruß und Lebenssinn. Opladen: Westdeutscher Verlag.
- Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. Science Education, 84(6), 740–756.
- Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. Science Education, 95(6), 1049–1065.

- Bybee, R.W. (1997). Achieving Scientific Literary: From Purposes to Practices. Portsmouth, NH: Heinemann.
- Bybee, R.W. (2000). Teaching science as inquiry. In van Zee, E.H. (Ed.), Inquiring into Inquiry Learning and Teaching Science. Washington, DC: AAAS. pp 20–46.
- Bybee, R.W., Powell, J.C & Trowbridge, L.W. (2008). Teaching Secondary School Science: Strategies for Developing Scientific Literacy. Upper Saddle River, NJ: Pearson Education (9th Edition).
- Chiappetta, E.L. (1997). Inquiry-based Science: Strategies and Techniques for Encouraging Inquiry in the Classroom. The Science Teacher, 64(10), pp 22-26.
- Csikszentmihalyi, M. & LeFevre, J. (1987). The experience of work and leisure. Journal of Personality and Social Psychology, 56, 815-822.
- Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behavior. New York, NY: Plenum.
- Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. Psychological Bulletin, 125(6), 627–668.
- Furnham, A., & Chamorro-Premuzic, T. (2004). Personality and intelligence as predictors of statistics examination grades. Personality and Individual Differences, 37(5), 943–955.
- Gläser-Zikuda, M., Fuß, S., Laukenmann, M., Metz, K. & Randler, C. (2005). Promoting stu-dents‗ emotions and achievement – conception and evaluation of the ECOLE approach. Learning and Instruction, 15, 481-495.
- Gläser-Zikuda, M. & Fuß, S. (2008). Impact of teacher competencies on students' emotion - a multi-method approach. International Journal of Educational Research, 47, 136-147.
- Glynn, S. M., & Koballa Jr., T. R. (2006). Motivation to learn in college science. In J. J. Mintzes & W.H. Leonard (Hg.), Handbook of college science teaching (pp. 25–32). Arlington, VA: NSTA Press.

- Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. Journal of Research in Science Teaching, 46(2), 127–146.

- Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire-II: Validation with science majors and nonscience majors. Journal of Research in Science Teaching, 48(10), 1159–1176 Harlen, W. (Ed) (2010). Principles and Big Ideas of Science Education. Hatfield: ASE.

- Hidi, S., Renninger, K.-A. & Krapp, A. (1992). The role of interest in learning and development. Hillsdale: Erlbaum.

- Hounsell, D. & McCune, V. (2003). 'Students' experiences of learning to present'. In: C. Rust, C. (ed.) Improving Student Learning Theory and Practice – Ten Years On. Proceedings of the Tenth International Symposium on Improving Student Learning, Brussels, September 2002. Oxford: CSLD. pp. 109-118.

- Kelly, U. and McNicoll, I. 2011 Through a glass, darkly: Measuring the social value of universities Bristol, UK: NCPE

- Krystyniak, R., A & Heikkinen, H.W. (2007). Analysis of Verbal Interactions During an Extended Open-Inquiry General Chemistry Laboratory Investigation. Journal of Research in Science Teaching, 44(8), pp 1160-1186.

- Linn, M.C., Davis E.A. & Bell, P.L. (2004) Inquiry and Technology. In M.C. Linn, E.A. Davis & P.L. Bell (Eds.), Internet environments for science education. Mahwah, NJ: Lawrence Erlbaum Associates. pp 3-27.

- Lovelace, M., & Brickman, P. (2013). Best practices for measuring students' attitudes toward learning science. Cell Biology Education, 12(4), 606–617.

- Mayring, P. (2009). Freude und Glück. In V. Brandstätter & J.H. Otto (Hrsg.), Handbuch der Allgemeinen Psychologie – Motivation und Emotion (pp. 585 – 595). Göttingen Hogrefe.

- Minner, D.D., Levy, A.J. & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. Journal of Research in Science Teaching, 47, pp 474–496.

- National Research Council (NRC) (1996). The National Science Education Standards. Washington, D.C.: National Academy Press.
- National Research Council (2000). Inquiry and the National Science Education Standards: A guide for teaching and learning. Washington D.C.: The National Research Council. OECD (2013). PISA 2012
- Assessment and Analytical Framework: Mathematics, Reading, Science, Problem Solving and Financial Literacy. Paris: OECD Publishing. http://dx.doi.org/10.1787/9789264190511-en OECD (2014). PISA 2012
- Results: Creative Problem Solving: Students' Skills in Tackling Real-Life Problems (Volume V). Paris: OECD Publishing. http://dx.doi.org/10.1787/9789264208070-en Pajares, F. (1996).
- Self-efficacy beliefs and mathematical problem-solving of gifted students. Contemporary Educational Psychology, 21(4), 325–344. Pajares, F. (2002).
- Gender and perceived self-efficacy in self-regulated learning. Theory into Practice, 41(2), 116–125. Palmer, D. H. (2009).
- Student interest generated during an inquiry skills lesson. Journal of Research in Science Teaching, 46, 147–165. Randler, C; Hummel, E; Gläser-Zikuda, M; Vollmer, C; Bogner, FX; Mayring, P:
- Reliability and validation of a short scale to measure situational emotions in science education, International Journal of Environmental & Science Education, 6(4), 359-370 (2011) Rothstein, M. G., Paunonen, S. V., Rush, J. C., & King, G. A. (1994).
- Personality and cognitive ability predictors of performance in graduate business school. Journal of Educational Psychology, 86(4), 516–530. Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H. & Hemm, V. (2007).

- Science Education Now: A Renewed Pedagogy for the Future of Europe. Brussels: Directorate General for Research, Science, Economy and Society. Rummler, G.A., Brache A.P. (1995).
- Improving Performance. Jossey-Bass Publishers. Tamir, P. (1985).
- Content analysis focusing on inquiry. Journal of Curriculum Studies, 17(1), pp 87-94. Ryan, R. M., & Deci, E. L. (2000).
- Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology, 25(1), 54–67. Schumm, M; Bogner, FX (2016):
- Measuring adolescent science motivation, International Journal of Science Education, 38(3), 434-449 (2016), doi:10.1080/09500693.2016.1147659 Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008).
- Motivation in education. Theory, research, and applications. Upper Saddle River, NJ: Pearson/Merrill Prentice Hall. Schwab, J.J. (1962). The teaching of science as inquiry. In Brandwein, P.F. (Ed.),
- The Teaching of Science. Cambridge: Harvard University Press. Singh, K., Granville, M., & Dika, S. (2002).
- Mathematics and science achievement: Effects of motivation, interest, and academic engagement. The Journal of Educational Research, 95(6), 323–332. Sotiriou, M., Mordan, C., Murphy, P., Lovatt, J., Sotiriou, S., Bogner, F., (2017) Sotiriou, S., & Bogner, F. X. (2011).
- Inspiring Science Learning: Designing the Science Classroom of the Future. Advanced Science Letters, 4(11-12), pp. 3304-3309. Sotiriou, S., Bogner, F., and Neofotistos, G.,
- Quantitative Analysis of the Usage of the COSMOS Science Educational Portal, Journal of Science Education and Technology (2011) 20:333-346 DOI 10.1007/s10956-010-9256-1 Sotiriou, S., Riviou, K., Cherouvis, S., Chelioti, E., & Bogner, F.X. (2016).

- Introducing Large-Scale Innovation in Schools. Journal of Science Education and Technology, pp. 1-9. Spielberger, C. D., Gorsuch, R. L. & Lushene, R.E. (1970).

- State-Trait Anxiety Inventory, Ma-nual for the State-Trait Anxiety Inventory; Palo Alto, CA: Consulting Psychologist Press.Strack, F., Argyle, M. & Schwarz, N. (Eds.). (1990).

- Subjective well-being. Oxford: Pergamon.Ulich, D., & Mayring, P. (1992). Psychologie der Emotionen (Psychology of emotions). Stuttgart, Kohlhammer.Zion, M, Slezak, M, Shapira, D, Link, E, Bashan, N, Brumer, M, Orian, T, Nussinowitz, R, Court, D, Agrest, B, Mendelovici, R, Valanides, N, . (2004).

- Dynamic, Open Inquiry in Biology Learning. Science Education, 88(5), pp 728-753.Zeyer, A. T., Çetin-Dindar, A., Md Zain, A. N., Juriševič, M., Devetak, I., & Odermatt, F. (2013).

- Systemizing: A cross-cultural constant for motivation to learn science. Journal of Research in Science Teaching, 50(9), 1047–1067.

8

ANNEX 1

NEEDS ANALYSIS SURVEY

8 ANNEX 1: NEEDS ANALYSIS SURVEY

Introductory Note
This is a short survey addressed to primary and secondary school teachers, head teachers, teacher trainers and educators to collect their feedback on the experiences, challenges, and opportunities in their teaching practice as the world adapts to the “new normal” caused by the COVID-19 pandemic. The survey is part of a needs analysis conducted by the EU funded Erasmus+ project *Playing with Protons Goes Digital*. The project aims at advancing the utilisation of new technologies that can facilitate an engaging, open, and digitally resilient science classroom. Within the project the emphasis is on building teacher digital competences by providing teachers and educators with an integrated toolkit that would enable them to co-design online creative STEAM* resources that “speak” to the digital habits, needs, and interests of their students. Thank you for your answers and precious time! *The acronym STEAM stands for the cross-curriculum study of Science, Technology, Engineering, Arts, and Mathematics
Disclaimer
The personal data that may be collected by filling out this form (name, email,) is processed by the consortium of the *Playing with Protons Goes Digital* project and in order to build a stakeholder community. By filling out this form, you consent to have your data used in the project and you acknowledge you have been provided the appropriate information. Your data will only be used in the context of the *Playing with Protons Goes Digital* project, and will not be shared with any other third party. It will be kept for a maximum of five years after the end of the project and in accordance with the project’s obligations to the EC. All data processing will be in accordance with the GDPR and national applicable law. You are not obliged to provide us with any data, but if you do decide to do so, we have marked the fields which are mandatory for us to have a useful entry. You have the right to withdraw your participation and consent for the processing of your personal data at any time, also after filling out and submitting the form, if you happen to change your mind. In addition, you have other rights, like the right to access, the right to rectification (update or correct data), the right to erasure, the right to restriction of processing and the right to data portability. To exercise your rights, you may contact us at [*add partner’s email per country*]. If you are still unhappy after that, you have the right to submit a complaint with a supervisory authority. If you simply have a question about this processing or about the *Playing with Protons Goes Digital* project, please also contact us at [*add partner’s email per country*].

Questions
Section 1: General Information
School [dropdown menu with choices filled out by the partners according to the education system in each of the four countries]
Job title (e.g., teacher, principal)
What subjects do you teach?
What grades do you teach?
Section 2: Teaching during COVID-19 In this section we would like to hear your and your students' experiences during your school's lockdown as a result of the COVID-19 pandemic.
How would you describe your overall experience with distance teaching during your school's lockdown? What were some of the critical challenges that you and your students faced during that time?
Teaching science in school sometimes includes hands-on experiments, simulations but also play-based activities such as educational card games, art, etc. in the classroom/school lab/outdoors. In the absence of face-to-face teaching during school lockdown, did you use in your distance teaching any digital tools to substitute for what you were normally doing in school? If yes, can you please describe them and also state the extent to which you and your students were satisfied with them?
Teaching science sometimes also includes out-of-school activities such as educational fieldtrips to museums, research institutes, science centres, science festivals, etc. In the absence of these opportunities during school lockdown, did you use any online environments to substitute for out-of-school activities? If yes, can you please describe them and also state the extent to which you and your students were satisfied with them?

If you were asked to advise your educational authorities, what would you say teachers and schools need most in order to continue provide their students with high-quality in-school but also out-of-school learning activities that respond successfully to the challenges of COVID-19?
Section 3: Teaching after COVID-19 In this section, we would like to hear your views on certain aspects of the structure and organisation of the science curriculum that may work more or less well in the face of major disruptive events such as the COVID-19 pandemic.
How would you imagine the ideal school experience for your students after experiencing remote schooling during the COVID-19 pandemic?
What recommendations would you make to your school and/or educational authorities in order to align best the science curriculum with the need for switching between face-to-face and to remote teaching if necessary?
Section 4: Teaching Needs after COVID-19 In this section, we would like to learn about whether and in what ways your needs as a science teacher or educator have changed after COVID-19.
Have your needs changed as a result of COVID-19? If yes, can you please describe your new needs?
What kind of support (e.g., online resources, digital tools, training, etc.) would you consider important in order to meet those needs?
How would you describe the ideal learning environment for your students under the “new normal”? If you were asked to advise your educational authorities, what would you say teachers and schools need most in order to continue provide their students with high-quality in-school but also out-of-school learning activities that respond successfully to the challenges of COVID-19?

Section 5: New Technologies in Science Teaching
Have you heard of Augmented Reality (AR) or Virtual Reality (VR) technologies?
If yes, can you name any AR or VR platforms or apps that are used in education?
Have you implemented AR or VR in your science classroom?
Would you find it useful to include AR or VR to support your science teaching?
Would be interested to be trained on how to apply AR or VR technologies and methodologies to your science teaching?
Section 6: Participate in Playing with Protons Goes Digital
I see educational value in a freely available digital toolkit with exciting STEAM activities inspired by cutting-edge science at world-renowned laboratories (such as CERN) that can support both traditional and remote teaching.
I would like to be kept updated with upcoming events and workshops organised by *Playing with Protons Goes Digital* in [add country] please feel free to add your name and email address below. [optional]
If your answer to the above question is "Yes", please feel free to add your name and email address below. [optional]

9

ANNEX 2

MULTIPLIER EVALUATION QUESTIONNAIRE MODEL

9 ANNEX 2: MULTIPLIER EVALUATION QUESTIONNAIRE MODEL

Dear Participant,

We appreciate a lot for taking part in the *Playing with Protons Goes Digital* Multiplier Event that took place in [add place and date here]. This evaluation form was designed to help us collect feedback from you as a participant to this event. Your opinion is important to us and will be used to increase our service level and make our next event more effective for participants.

We thank you in advance for the time and effort you are investing in filling out this form!

Disclaimer

The personal data that may be collected by filling out this form is processed by the consortium of the Playing with Protons Goes Digital project and to build a stakeholder community. By filling out this form, you consent to have your data used in the project and you acknowledge you have been provided the appropriate information. Your data will only be used in the context of the Playing with Protons Goes Digital project and will not be shared with any other third party. It will be kept for a maximum of five years after the end of the project and in accordance with the project's obligations to the EC. All data processing will be in accordance with the GDPR and national applicable law.

You are not obliged to provide us with any data, but if you do decide to do so, we have marked the fields which are mandatory for us to have a useful entry. You have the right to withdraw your participation and consent for the processing of your personal data at any time, also after filling out and submitting the form, if you happen to change your mind. In addition, you have other rights, like the right to access, the right to rectification (update or correct data), the right to erasure, the right to restriction of processing and the right to data portability.

To exercise your rights, you may contact us at [add partner's email per country]. If you are still unhappy after that, you have the right to submit a complaint with a supervisory authority.

If you simply have a question about this processing or about the Playing with Protons Goes Digital project, please also contact us at [add partner's email per country].

Questions	1 Extremely Poor	2 Poor	3 Average	4 Very Good	5 Excellent
1. To what extent did the content of the event address your expectations?					
2. How satisfactory was the agenda of the event?					
3. How would you rate the quality of the presentations?					
4. How would you rate the usefulness of the presentations from your own perspective?					
5. How would you rate the content of the presentations?					
6. Was the content of the presentations helpful for increasing your level of awareness about the role of advanced digital technologies in supporting both traditional and remote STEAM teaching?					
7. Were the speakers well prepared and engaging?					
8. Was the location chosen for the event convenient?					
9. How would you rate the overall organization of the event?					
10. How would you rate the opportunities for networking during the event?					

	1 No	2 Probably not	3 Maybe	4 Probably yes	5 Yes
11. Do you think that you could consider using the *Playing with Protons Goes Digital* concept, methodology and tools in your practice?					
12. Would you recommend the Playing with Protons Goes Digital project to your colleagues?					

1. What future training needs do you expect to occur, which you would like to be addressed?

2. Do you have any suggestions for follow-up events or actions to set up?

10

ANNEX 3

TEACHERS' QUESTIONNAIRE REPORT MODEL

10 ANNEX 3: TEACHERS' QUESTIONNAIRE REPORT MODEL

Dear teacher,

Thank you for your participation!

All questionnaires are part of a study, and your answers are strictly confidential! The questionnaire is anonymous, all we need: the name, school grade and class of your school and your gender.

Name of your school: ____

- ☐ Primary school
- ☐ Middle school
- ☐ Hight school

Class: ____

- ☐ Female
- ☐ Male
- ☐ Other
- ☐ I don't want to say

Questions

To better understand what you think and how you feel about your scientific experience with the scenarios and AR/VR tools used, answer each of the following statements.

	1 Extremely Poor	2 Poor	3 Average	4 Very Good	5 Excellent
1. How would you rate the quality of the scenario topics?					
2. How would you rate the usefulness of the scenarios into curricular activities?					
	1 No	**2** Probably not	**3** Maybe	**4** Probably yes	**5** Yes
3. Was the activity helpful for increasing your level of awareness about the role of advanced digital technologies in supporting STEAM teaching?					
4. Can your school infrastructure support the realization of AR/VR related activities like *Playing with Protons Goes Digital*?					
5. Do you think that you could consider using the *Playing with Protons Goes Digital* concept, methodology and tools in your practice?					
6. Would you recommend using the scenarios' and AR tools' *Playing with Protons Goes Digital* to your colleagues?					

1. Do specific *Playing with Protons Goes Digital* activities influence the students' general motivation. Which ones and why?

2. Are there gender differences? Please explain in few words.

3. What emotions have students at Playing with Protons Goes Digital activities? Please explain using examples.

4. Do specific Playing with Protons Goes Digital activities influence the students' cognitive load? Which ones and why?

5. What are the most interesting and relevant aspects of the Playing with Protons Goes Digital proposed digital approaches?

6. What are the main innovative elements?

7. Is the Playing with Protons Goes Digital portal useful to your day-to-day work and why?

8. Which parts of digital approaches of the Playing with Protons Goes Digital project need improvement?

9. What barriers are there to integrate of the Playing with Protons Goes Digital digital approaches at your school?

10. Are organizational changes required to implement the project to the school environment? Which ones?

11

ANNEX 4

PRE SMQII

STUDENT'S QUESTIONNAIRE

11 ANNEX 4: PRE SMQII - STUDENT'S QUESTIONNAIRE

PRE Questionnaire students

Dear student,

Thank you for your participation!

All questionnaires are part of a study, and your answers are strictly confidential! The questionnaire is anonymous, all we need your age, gender, and the name of your school.

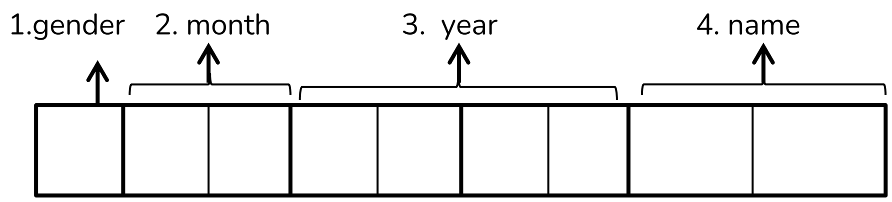
- Work accurately on the tests on your own!
- Use pen, not pencil!
- Marc with a cross the answers that are right to your own opinion!
- Please answer all questions!
- Do not speak about third parties. Answer according to your own opinion.

To fill in the **pre** and **post** questionnaire you must use **the same code** built in the following way:

Your personal code:

Your personal Code is built up of:

1. your gender: girl is female (F) or boy is male (M), Other (O), I don't want to say (D)
2. your month of birth (e.g. 01, 02, 03, ..., 12)
3. your year of birth (e.g. 2005, 06, 07, ...11,12,13)
4. the two first letters of your name (e.g., AN for Anna)



Example: *Student is a boy, i.e. male, born in January 2005; his name is Antony.*

Student's code is:

M	0	1	2	0	0	5	A	N

PRE SMQII – Student's Questionnaire

Name of school: ____

Age: ____

- ☐ Female
- ☐ Male
- ☐ Other
- ☐ I don't want to say

CODE

To better understand what you think and how you feel about to study science, please respond to each of the following statements.

For each of the following statements, please indicate how true it is for you, using the following scale **(SMQII: from 1 very little.... to 5 very much)**.

	1 Very little	**2** Little	**3** Average	**4** Much	**5** Very much
1. Learning science is interesting.					
2. The science I learn is relevant to my life.					
3. I enjoy learning science.					
4. Learning science will help me identify the best course of study for my future.					
5. Understanding science will benefit me in my studies.					
6. I will use science problem-solving skills in my studies.					
7. The choice of future studies will concern science.					
8. I spend a lot of time learning science.					
9. I believe I can earn a good grade in science.					
10. I believe I can master science knowledge and skills.					
11. Getting a good science grade is important to me.					

12

ANNEX 5

POST SMQII

STUDENT'S QUESTIONNAIRE

12 ANNEX 5: POST SMQII - STUDENT'S QUESTIONNAIRE

POST Questionnaire students

Dear student,

Thank you for your participation!

All questionnaires are part of a study, and your answers are strictly confidential! The questionnaire is anonymous, all we need your age, gender, and the name of your school.

- Work accurately on the tests on your own!
- Use pen, not pencil!
- Marc with a cross the answers that are right to your own opinion!
- Please answer all questions!
- Do not speak about third parties. Answer according to your own opinion.

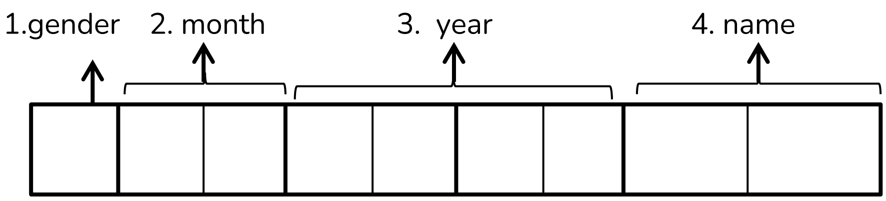
To fill in the **pre** and **post** questionnaire you must use **the same code** built in the following way:

Your personal code:

Your personal Code is built up of:

5. your gender: girl is female (F) or boy is male (M), Other (O), I don't want to say (D)
6. your month of birth (e.g. 01, 02, 03, ..., 12)
7. your year of birth (e.g. 2005, 06, 07, ...11,12,13)

8. the two first letters of your name (e.g., AN for Anna)



Example: *Student is a boy, i.e. male, born in January 2005; his name is Antony.*

Student's code is:

M	0	1	2	0	0	5	A	N

POST SMQII – Student’s Questionnaire

Name of school: ____

Age: ____

- ☐ Female
- ☐ Male
- ☐ Other
- ☐ I don’t want to say

CODE

To better understand what you think and how you feel about to study science, please respond to each of the following statements.

For each of the following statements, please indicate how true it is for you, using the following scale **(SMQII: from 1 very little.... to 5 very much)**.

	1 Very little	2 Little	3 Average	4 Much	5 Very much
1. Learning science is interesting.					
2. The science I learn is relevant to my life.					
3. I enjoy learning science.					
4. Learning science will help me identify the best course of study for my future.					
5. Understanding science will benefit me in my studies.					
6. I will use science problem-solving skills in my studies.					
7. The choice of future studies will concern science.					
8. I spend a lot of time learning science.					
9. I believe I can earn a good grade in science.					
10. I believe I can master science knowledge and skills.					
11. Getting a good science grade is important to me.					

13

ANNEX 6

IMI STUDENT'S QUESTIONNAIRE

13 ANNEX 6: IMI STUDENT'S QUESTIONNAIRE

To better understand what you think and how you feel about to study science, please respond to each of the following statements.

For each of the following statements, please indicate how true it is for you, using the following scale **(IMI: from 1 very little.... to 5 very much)**.

	1 Very little	**2** Little	**3** Average	**4** Much	**5** Very much
1. I believe that AR/VR tools and scenarios helped me to understand some scientific topics.					
2. I would like to develop augmented reality objects that explain scientific phenomena.					
3. I enjoyed doing this activity very much.					
4. I thought this was a boring activity.					
5. This activity did not hold my attention at all.					
6. I would describe this activity as very interesting.					
7. After working at this activity for a while, I felt competent.					
8. I am satisfied with my performance at this task.					
9. I was skilled at this activity.					
10. This was an activity that I couldn't do very well.					

11. I was anxious while working on this task.					
12. I felt pressured while doing this activity.					
13. I felt like I had to do this.					
14. I did this activity because I had no choice.					

WEBSITE

www.digitalprotons.eu

SOCIAL

Facebook
@digitalprotons

Instagram
@digitalprotons

Twitter
@digitalprotons

PARTNERS

INFN Istituto Nazionale di Fisica Nucleare

ELLINOGERMANIKI AGOGI

FONDAZIONE IDIS CITTA'DELLASCIENZA

CreativiTIC We Make Things Happen!!! www.creativitic.com

UNIVERSITY OF BIRMINGHAM