SciChallenge: A Social Media Aware Platform for Contest-Based STEM Education and Motivation of Young Students

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Abstract—Scientific and technological innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy. Still, enrolment rates in STEM degrees are low in many European countries and consequently there is a lack of adequately educated workforce in industries. We believe that this can be mainly attributed to pedagogical issues, such as the lack of engaging hands-on activities utilized for science and math education in middle and high schools. In this paper, we report our work in the SciChallenge European project, which aims at increasing the interest of pre-university students in STEM disciplines, through its distinguishing feature, the systematic use of social media for providing and evaluation of the student-generated content. A social media-aware contest and platform were thus developed and tested in a pan-European contest that attracted >700 participants. The statistical analysis and results revealed that the platform and contest positively influenced participants STEM learning and motivation, while only the gender factor for the younger study group appeared to affect the outcomes (confidence level – $p<.05$).

Index Terms— Computer and Information Science Education, Social and Behavioral Sciences, STEM Education, Collaborative learning, Software engineering for Internet projects, Computers and Society.

1 Introduction

Europe's major aim for the next decade is to become the most innovative community with significant economic growth. As research and development are key factors for achieving this growth, Europe needs a larger workforce educated in Science, Technology, Engineering and Math (STEM). Achieving the target of investing 3% of EU GDP on R&D by 2020 could create 3.7 million jobs and increase annual GDP by €795 billion by 2025 [1]. However, considering the current trends in the number of STEM graduates, it will be hard to find suitable candidates for the available R&D jobs in future.

While it is recognized that science and technology are of key importance for future development and for maintaining the already high quality of life in Europe, the current interest for STEM related education and careers among young people is low in many European countries. For example, France had less than 20% STEM graduates in 2016, while China had 40% [2]. However, the STEM fields provide increasing job opportunities as indicated in the comparison of the STEM-related growth (12%) and general employment growth (4%) in the EU-28 countries for the period 2003-2013 [3]. Also different forecasts draw a similar picture, and show that this number varies within the STEM-sectors. Thus, the expected growth rate for the employment in professional services (2014-2025) is 15%, in computing (2014-2025) is 8%, while for example in the pharmaceuticals sector is ~0% [4].

On the contrary, there is a declining supply of STEM-secondary education graduates in Europe between 2006 and 2011. The EU-average in 2006 was 32%. In 2011, the EU-average declined to 29% [4]. Furthermore, problematic gender relations in the STEM-fields in Europe exist as well. Whereas the proportion of women with science and engineering degrees was 38% in North America in 2014, Europe only reached 25% [5].

A recent report of the SCIENTIX project presents a study of national measures in 30 EU countries, which are aiming to increase the interest of students in STEM education and careers [6]. About 80% of the countries considered STEM education as a national priority at the national level and they are currently developing strategies for improving teaching and learning in STEM disciplines.

Many traditional STEM contests[1] for pre-university students have been devised recently in an attempt to address the above issues. Modern science contests though should consider the lifestyle of the target participants who routinely use social networks for interacting and cooperating with each other. They are not only passive consumers of the content produced by an authoritative

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Manuscript Received: 30 Aug. 2017.

[1] Student Competitions – https://studentcompetitions.com

provider, but they actively create, share and judge the content with other users.

SciChallenge (Next Generation Science Challenges Using Digital and Social Media to Make Science Education and Careers Attractive for Young People) [7] is an H2020 EU funded project that aims to raise the attractiveness of science education and scientific careers to young people, to boost their interest in STEM, and to introduce innovative and effective teaching and education methods by:

- Elaborating a novel concept for science challenges involving young people producing scientific content for young people in a creative way.
- Building a student contest web platform that includes an open information hub with resource directories, a contest submission system with syndication features, social sharing functionalities and awareness channels.
- Spreading the idea of SciChallenge using social media channels and innovative promotion activities targeting young people.
- Conducting the contest all over Europe with several contest categories (single, group, class) and various creative submission types (videos, infographics, slides, comics) to foster science education among young people and enabling them to work with research knowledge resources.
- Attracting young people for scientific careers by integrating cross-sectorial awareness modules on the web platform like interactive science organisation profiles, an internship and exchange and tasters day exchange directory, participative science event navigator or university test study listings.

The major contributions of this paper include:

1. The SciChallenge framework for educating and motivating pre-university students for STEM education and careers;
2. Development of a social media-aware platform for realisation of the SciChallenge framework;
3. Evaluation of SciChallenge concept and platform via user experience questionnaires;
4. Documenting the observations derived from organization of a pan-European SciChallenge contest with more than 700 participants.

The rest of the paper is structured as follows. We discuss the related work in Section 2, the SciChallenge concept in Section 3, and describe the SciChallenge web platform architecture and functionality in Section 4. The results were obtained from the use of the platform by participants in the period from Jan 1st to May 15th, 2017, exploring the platform and submitting their STEM projects. These are reported in Section 5. Section 6 provides a discussion on the motivational impact of the SciChallenge web platform in enhancing interest in STEM. Conclusions and future work are presented in Section 7.

2 Related Work

Beyond the extended methods used in schools, the EU invests significant effort and financial resources to promote STEM. As a result, many new international educational platforms, toolkits, and more have come to life during the last years, few of which will be mentioned.

The European Schoolnet[2] is actively initiating and participating in projects that promote science career via development of science teaching. In the Amgen Teach project, the School Network is providing technical assistance as a hub. The programme itself is for supporting the teachers to deepen student interest in science by providing tools and equipment for teachers to use inquiry-based teaching strategies in the classroom. Apparently all of these indirectly involve students as the main targets of teachers, by providing them pedagogy and tools for raising the level of science education and student's interest.

The mission of the Quantum SpinOff EU project[3] is to connect schools with research companies in order to enable the students to connect the abstract knowledge with the real innovations in the area of nanoscience. The project aims to: "provide teachers with tools and a pedagogy to connect pupils with the 'life of real-life' researchers and so raise the societal visibility of this kind of life, which according to the mentioned study has a positive impact on the motivation of girls for STEM-careers."

The GoLab EU FP7 project [8] offers a web-based learning open platform including remote and virtual labs with experiments that can be displayed in the classroom and which are connected to the curriculum. Space awareness primarily targets primary and secondary school teachers inspiring them to teach the space subject.

Contest platforms, such as StudentCompetitions[1] and Big Ideas@Berkeley[4] also exist. The StudentCompetitions web platform allows registering or even creating a competition. The web platform enables people to register, find competitions and compete in the many contests that are available on the platform. Also, it promotes winners and enables users to share their results and awards with the world through social media. Big Ideas@Berkeley facilitates easy and efficient application of projects from students, as well as judging processes via their web platform. Judges can view proposals assigned to them through the platform and submit their scores and feedback, allowing for anonymous judging as well.

Manero et al. [9] study empirically the influence of factors such as the age or gaming profile of high-school students in the educational process in the context of an educational videogame. They observed that the gaming profile of high-school students affects the motivation of students not only in the game-based education but also in traditional education. Claros et al. [10] proposes to use social network metrics to study social interaction processes in the context of collaborative learning. Vassileva [11] studies the design of social learning environments using Web 2.0 technologies that may help the learner to find the right content, connect with other people and motivate the learner to learn. Ibanez et al. [12] study the use of gamification for teaching C-programming language. They observed positive effects on knowledge acquisition and cognitive engagement of students. Chen et al. [13] study

[2] European Schoolnet – http://www.eun.org/
[3] Quantum Spinoff Project - http://www.quantumspinoff.eu/
[4] Big Ideas@Berkeley – http://bigideas.berkeley.edu/toolkit-platform/

educational experiences of engineering students by mining Twitter posts. They observed that many students consider that engineering is difficult and not interesting, and this negatively impacts motivation to study. Chozas et al. [14] propose a cognitive computing solution for learning parallel programming based on the IBM Watson.

Many traditional STEM contests for pre-university students exist as well. For instance, the International Mathematical Olympiad is organized since 1959 as an annual world competition in mathematics for high school students. The world competition in chemistry for high school students, the International Chemistry Olympiad, is organized since 1968. The Intel Science Talent Search (formerly Westinghouse Science Talent Search) competition for the 12th grade of secondary school is organized since 1942. Since the mid of the 20th century the advancement in ICT has been tremendous and has changed the way we live, learn and work. According to ITU in 2015 more than 82% of households in Europe had Internet access. In UK, 96% of young people in the age range 13 to 18 have an account in social media.

Table 1. Examples of STEM contests for pre-university students.

STEM contest	Participants	Type of challenge/task	Scale
International Olympiads (math, physics…)	Secondary school, under the age of 20	A set of theoretical and practical problems defined by the contest organizers	Global
Beavers of Computer Science	Age 8 – 20	Multiple-choice questions	Country-level: AU,AT,..
Intel International Science and Engineering Fair	Grades 9 – 12	Any project defined by contestants that fits in one of the predefined categories	Global
Intel Science Talent Search	12th grade of secondary school	Any project of contestants that fits in one of the predefined categories	USA
Siemens Competition in Math, Science and Technology	Grades 9 – 12	Any project of contestants that fits in one of the predefined topics	USA
Junior Science and Humanities Symposia	Grades 9 – 12	Any project defined by contestants that fits in one of the predefined categories	USA
International BioGENEius Challenge	Grades 9 – 12	Projects that have application to biotechnology are eligible	Global
Conrad Spirit of Innovation Challenge	Age 13 – 18	Any project idea that fits in the four predefined categories	Global
Google Science Fair	Age 13 – 18	Projects of contestants that fit one of the predefined categories and topics	Global
EU Contest for Young Scientists	Age 14 to 21	A project in any field of science	EU

As shown in Table 1 there are many contests, projects and initiatives for generating interest in STEM. A very important dimension that needs to be further exploited is Web 2.0. In fact, the advent of Web 2.0 has changed the way we create and use content. Also, in Web 2.0 the roles of content creator and consumer are blurred, where users are provided a service and create (generate) the content. As stated in [15]: "*This community participation in the creation of shared resources is made possible by Web 2.0 technologies in which individuals make material available to be used and modified by others*."

Another important dimension of Web 2.0 is that it enables linking humans and organizations in what is known as social networks or social media [16]. To highlight the importance of the social media dimension, in 2008 the European Commission under the umbrella organisation Marie Skłodowska Curie actions Research Fellowship Programme released an inspiring educational video for chemical research. The video is targeting youngsters and it is designed in a funny way at the level of juveniles. With over 2.5 million views and hundreds of comments the video was a huge success. The above and the fact that the *hashtag* ***#scichallenge*** *is not in use highlights,* show that a digital science challenge is of utter importance.

In China, US, Singapore and Canada several expert programmes use innovative approaches to attract and raise the interest of young students and in particular female students in STEM. For instance, She Loves Tech[5] is a leading Chinese initiative founded by Lean In China and Tech Rock, which in 2017, kicked off with a global startup competition held in multiple locations across the world (e.g., Canada, China) with the finals held during an international conference in Beijing, China. The goal is to provide a platform for international and Chinese technology companies, investors, startups and consumers together, to promote technology for women.

Also, the Hong Kong Science and Technology Parks (HKSTP) is a non-profit, government-funded body that promotes STEM education to local primary and secondary pupils, via a range of events and activities. Notably, the HKSTP sponsored 20 secondary schools in the Tai Po District to purchase the kind of equipment that can enhance their teaching of robotics, where pupils' works are being displayed at the end of each school year[6]. Other initiatives include Qualcomm's STEM education models[7], one of which engages with young professional women by providing scholarships and mentorships in China, India, Korea and Taiwan. Finally, a US non-profit organisation called Technovation, is the largest global technology and entrepreneurship challenge[8] that invites girls to build mobile apps that will address a community problem.

The SciChallenge project framework aims to make outer use of the above concepts of user-generated content and social networks. This is because the above concepts are not fully exploited in previous works, something that the SciChallenge project aims to address in an effort to define the next generation of science contests (i.e., challenges). The project is studying and developing new concepts for STEM contests that take into consideration the state of the art in ICT. Thus, social networks are used not

[5] She Loves Tech - http://www.shelovestech.org/
[6] Robotics competition instils interest in STEM subjects in young people - https://goo.gl/5Rd9ap
[7] Qualcomm Global Scholars Program - https://goo.gl/dJsYp4
[8] Technovation Challenge - http://technovationchallenge.org/

only for sharing the contributions, but also for evaluation of the contributions. A weighted rank calculation approach combines the ranking of the contribution by the online community and the ranking by the jury to determine the final ranking of contestants. Moreover, the content generated and shared by SciChallenge contestants in social media may be used by other students for learning in the future, ensuring a long-term impact of the contest.

3 SciChallenge Framework

The three key pillars of the SciChallenge framework are social media, user-generated content and STEM contests. The SciChallenge framework aims at the exploitation of user-generated content and social networks, to increase its outreach to younger age groups and to both genders. As identified in STEM research works [25], [26] and explicitly stated in [23] and [24]:

1. "The majority (65%) of participants reported that their interest in science began before middle school."
2. "Females were more likely to report that their interest was sparked by school-related activities, while most males recounted self-initiated activities."
3. "Cultivating female interest in math and science" and
4. "Creating initiatives to influence the greater cultural sphere at the macro-level or by working directly with females at the micro-level to increase their interest."

Based on the above, the social media driven framework and the platform built in this work aim to attract interest at early ages and create a sociable and interesting initiative that has the potential to stimulate female interest and influence the cultural sphere. These concepts are applied at a Pan-European level with a total of 745 contest participants from 28 countries, and 437 projects (including group projects) submitted to the contest.

Conceptually, social networks may be represented and analysed using the graph theory [17]. A social network is a graph with nodes that represent humans and edges that represent relationships among them. A graph node may represent also an organization. In social sciences, the concept of social networks has been used since the first part of the 20th century to indicate the relationships among members of a social system.

The content produced by users of a service is known as user-generated content (UGC) or user-created content (UCC). OECD describes UCC as follows: "*i) content made publicly available over the Internet, ii) which reflects a certain amount of creative effort, and iii) which is created outside of professional routines and practices*" [2]. With respect to the use of UCC for education OECD states, "*Educational UCC content tends to be collaborative and encourage sharing and joint production of information, ideas, opinions and knowledge, for example building on participative web technologies to improve the quality and extend the reach of education*" [2].

UGC/UCC examples include, product reviews, blogs, wikis, news comments, photos, videos, status updates, tweets. Traditionally a small group of professionals used to create the content and distribute it via defined channels to many other people. UGC/UCC has democratized the process of creating and distributing the content. Today many people have the opportunity to create content and distribute it to many other people. An interesting example of UGC/UCC is Wikipedia, which is an encyclopaedia that is collaboratively written by its users. An investigation published in Nature [18] showed that Wikipedia is as accurate as Britannica with respect to science entries.

Competition is considered part of the human nature and is as old as humankind is. Historically, humans used to compete for resources as individuals or groups. As an instinctual drive in human nature, competition is a driving force of advancement in science and technology as well. The SciChallenge project uses the concept of contest (competition) to promote STEM disciplines and discover the talent among young people.

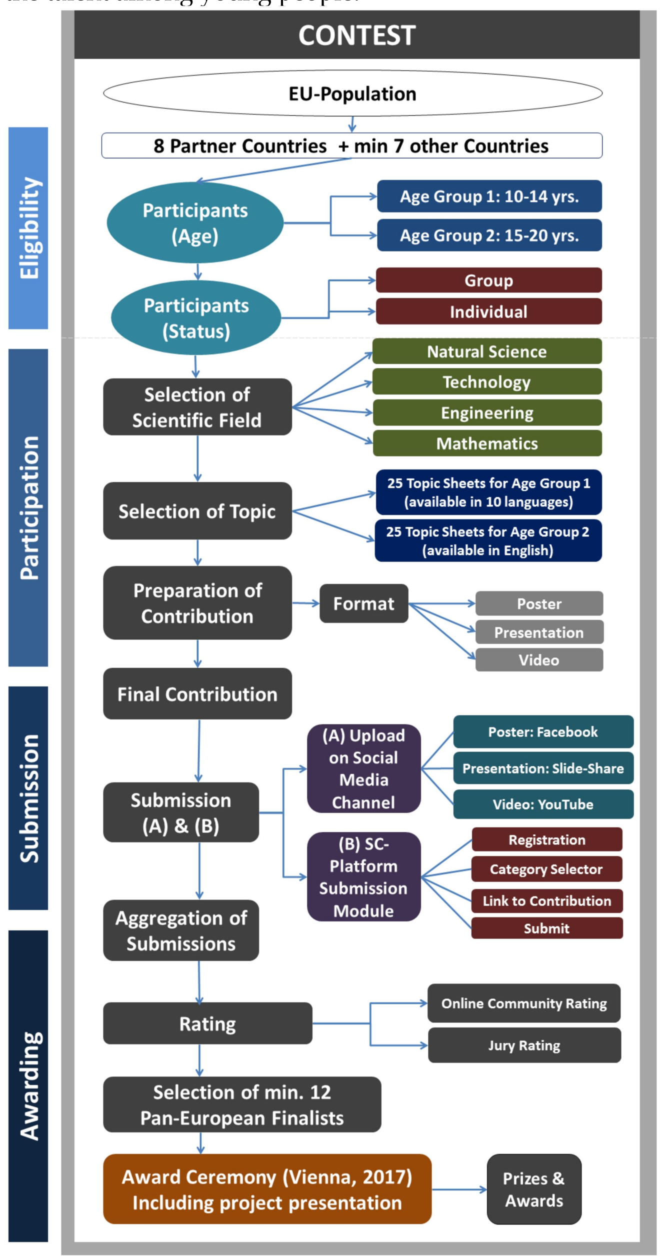

Fig. 1. SciChallenge Concept.

By exploiting the above concepts the project aims at a broad participation of children, teenagers and young adults from all EU-member states and H2020-associated

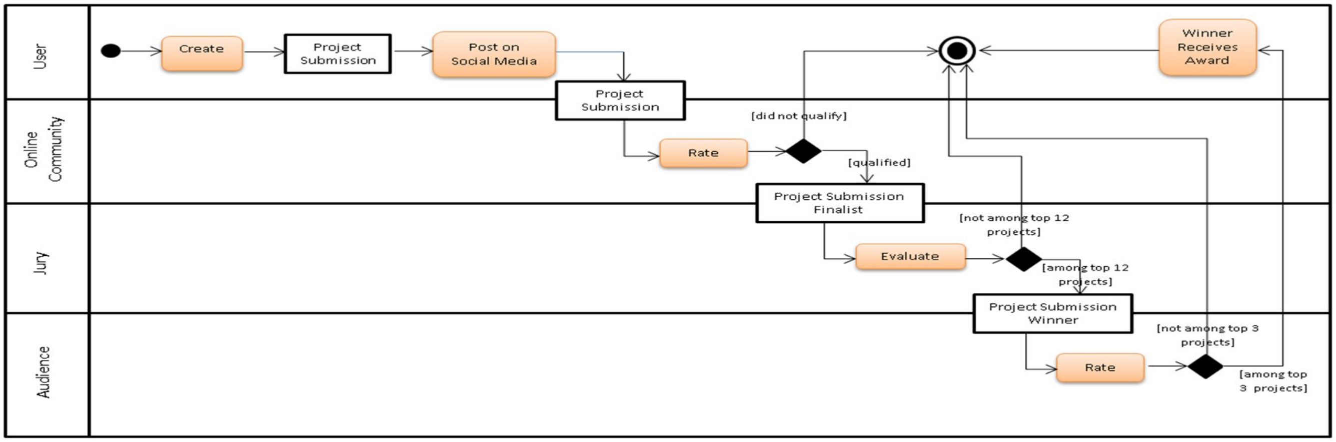

Fig. 2. The key activities of the SciChallenge platform.

countries. Eligible for participation are pre-university students between 10 to 20 years of age. Participants (and their submitted contributions) are categorized in two age groups: ***Age Group 1 (AG1) consists of 10-14 year old persons*** and ***Age Group 2 (AG2) includes 15-20 year old persons***. Students already enrolled at a university are not eligible to participate. From AG1, 204 projects were submitted and 233 projects from AG2. The contest was successful in achieving high female students' participation (419) and an analogous male students' participation (321).

Fig. 1 shows the SciChallenge contest concept. Contributions to the SciChallenge contest can be submitted as an individual or group project. In an individual project, a person works on his/her contribution alone and submits it as an individual. In a group project, participants work together as a group (maximum of 3 persons). Therefore, if a school class decides to participate, they must split-up into several groups and can either work on the same or different topics, or can even submit a contribution on the same topic but in different formats. Then, participants have to select a particular topic in one of the four major STEM disciplines: ***Natural Science***, ***Technology***, ***Engineering***, **or** ***Mathematics***.

In order to facilitate a large number of submissions, a total of 51 topic sheets have been implemented and made available on the SciChallenge platform (25 for each age group and one open STEM topic). A topic sheet is conceptualized as a single-page information sheet, which provides basic information about a particular topic, the societal challenges related to the issue, links to further information, an inspiring image or illustration, and one or more inspiring questions to help participants start reasoning about the topic. It is designed in a way to be appealing for girls and boys between the ages of 10 to 20. In fact, topic sheets aim to act as a catalyst, motivate participants and assist them to start working on their contributions.

Starting with the topic sheets, participants are expected to research further into their topic and prepare their contribution. The contributions can be prepared in 10 languages and should present the problem in a clear manner. This needs to include a scientific approach (based on existing knowledge), creativity regarding the realization, a demonstration of the added value that ensures a sustainable exploitation beyond the contest, and a presentation of ideas and future thinking aiming at addressing major challenges.

Participants can prepare and present their contribution in one of the following formats: ***Poster*** (suitable for intuitive, artistic, as well as more conceptual approaches to topics), ***Presentation*** (suitable for a more complex, science-oriented approach to a topic in order to present it in a structured way) or ***Video*** (especially suitable for artistic or story-telling approaches, as well as for documentation of experiments or animated examinations). The above-mentioned formats can also be used to present pieces of creative writing, may this be in the form of short stories, poems or essays – may this be in oral or written form – as long as the required standards of the formats are met.

For submitting their project, participants have to follow a 2-step process: i) the project is uploaded in one of the main social media sites (Slideshare for posters/presentations, Youtube for videos) that guarantee a broad distribution and intuitive functionalities, ii) participants register on the SciChallenge platform, create a personal and a project profile including the link to Slideshare or Youtube, and then they submit their contribution. The project profiles include the title, the language, a short description and the category of the contribution. In addition, participants are asked to provide a short description of their project in English on a non-mandatory basis to assist the jury during the evaluation procedure.

Privacy of the young students was of course enforced through various means in the process. Specifically, underage participants were required to get the consent of the parents to participate, while for registration and contest transparency only basic information were exposed on the platform. In terms of social media, students were able to upload their contribution using a pseudonym, to protect their privacy on these platforms. Also, they only had to include a link of the project in the submission portal.

4 SciChallenge Platform

The activities supported by the platform are illustrated in Fig. 2 in the form of an activity diagram. Firstly, the user creates the project and uploads it on the supported social media utilised by the platform, namely Youtube or Slideshare, in order to promote the project. Then the project submission is rated using the implemented rating functionality offered by the platform (utilizing likes and views from the social media platforms, see Section 4.4.1). Based on this score the project qualifies or not to the next stage. The project finalist is then evaluated by the expert members of the jury established by the SciChallenge project from which 12 projects are selected that receive as a price a trip to the final award event. The 12 winning submissions are then rated at the final event to select the 3 top projects that receive an award at the final event.

The SciChallenge web platform shown in Fig. 3 serves as the main hub for participation in the contest. It is developed using the latest web technologies such as the frontend UI web framework Bootstrap.js, the JSON data format, WordPress (i.e., PHP-based), JavaScript libraries and an MySQL database. Furthermore, it exploits the available Web APIs from well-known social media platforms to facilitate the contest participants, as well as to enable them to fully promote their project.

The web platform consists of the "Contest Area" and the "Awareness, Blogging and Sharing Area" (see Fig. 3).

The *"Contest Area"* includes information on the contest, general guidelines and the rules for the contest participation. It also includes the topic sheets described above. Also, educational resources are available for use in the form of a link collection, as well as links to science platforms. A ***submission module*** can be used for participating in the SciChallenge contest. It starts with user registration, proceeds with a category selection with the assistance of the topic sheets and the educational resources and ends with the submission. Finally, the project is automatically promoted to social media (i.e., Facebook and Twitter).

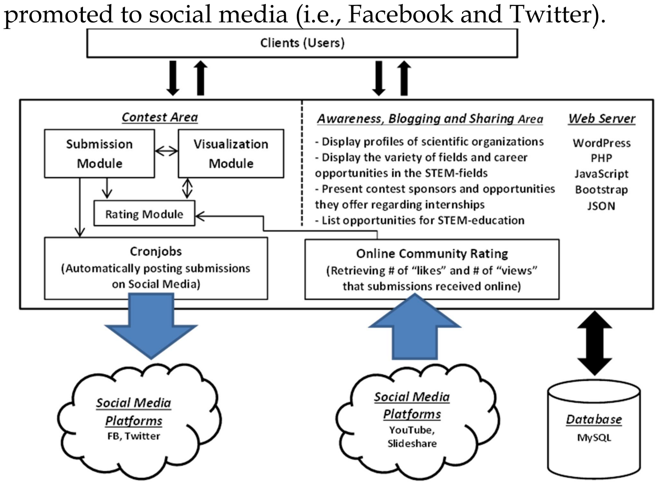

Fig. 3. SciChallenge Platform Architecture.

An important aspect of the web platform is the ***rating module***. The rating module initially uses a mathematical function to calculate the *Online Community Rating* based on the "likes" and "views" a submission has received on Youtube and Slideshare. From the online community rating, a number of projects will qualify as finalists. Next, the rating module enables a group of 39 jury members from various countries to evaluate the qualified projects by providing their own scores (*Jury Rating*) based on expert evaluation criteria. More information on the rating procedure is provided in Section 4.4.

Another important platform component related to the contest is the ***visualization module***. It is responsible for displaying submission statistics on the platform, such as top submissions, submissions per country, per topic, etc[9]. A filtering and searching mechanism is also available to facilitate the above. The country dashboard shows submissions per country on an interactive map.

The *"Awareness, Blogging and Sharing Area"* includes a section with profiles of scientific organizations, displaying the variety of fields and career opportunities in the STEM-fields. It also presents the sponsors of the contest and the opportunities they offer regarding internships. Additionally, it lists opportunities for STEM-education as well as science events aimed at young people in a meta-directory. Furthermore, it includes a blogging section, where participants and authors can share their experience, as well as sharing capabilities focusing on social media and links to other platforms.

In the next subsections we present in detail the process supported by the platform, as well as the key innovative features of the SciChallenge platform.

4.1 Dashboards

Dashboards serve as linkable hotspots (markers) within a map that depict submission information with location-awareness and other useful statistics[9].

The purpose is to provide the user with a location oriented view of the submissions uploaded on the platform. The dashboard offers also an advanced dashboard mode, currently disabled for simplicity purposes for the students, along with basic information such as submission title. Also the advanced dashboard mode provides more detailed information about a submission or a number of submissions that are somehow related, e.g. all submissions occurred from the location of Cyprus.

4.2 Social Awareness and Sharing

During the last decade, social networks have evolved to become an essential part of today's life. Many of them such as Facebook, LinkedIn and Twitter already have millions of users and the numbers are continuously increasing. A social network is in essence a social structure taking place over electronic communication means, where social actors (people acting as users) are connecting with each other to communicate and interact.

Considering the millions of users interacting on social networks on a daily basis, it is evident that the importance of continuously publishing SciChallenge web platform and contest information on those networks is eminent. However, to accomplish this, social awareness technologies and tools are needed to promote the contest, inform participants and the public and create social links and awareness around the contest over a number of social networks. We have considered a number of social networks for publishing SciChallenge material.

4.2.1 Use of Facebook

Facebook is currently the most widely used social network. Facebook is of extreme value because of its users. By using the tools provided by Facebook, one can reach millions of people for advertising, informational or other purposes. The SciChallenge official Facebook page was

[9] Statistics page - https://www.scichallenge.eu/en/statistics

created and used for promoting the SciChallenge web platform and contest, for attracting people to the contest and for sharing contest material such as user generated submissions and other information. User generated content is shared on SciChallenge official Facebook page, but also on the user's Facebook wall – with user consent.

The SciChallenge platform uses Facebook in two different ways. The first enables the user to share his/her SciChallenge contest submission on his/her own private Facebook wall by activating the classic blue Facebook "share" button on key locations on the web platform, and urging and motivating the user to share SciChallenge contest related information (such as their submitted project) on their Facebook wall. This is a very efficient way of reaching out to new users, as with every such Facebook post, all friends, relatives and contacts of the participating user learn about the SciChallenge contest and web platform, as well as the fact that their friend has participated and had so much fun by learning; so, why not try it themselves. This functionality is technically achieved by using a Facebook share button Javascript function, which utilizes the Facebook Javascript SDK. Once the button is clicked, the user is asked to log-in to Facebook (if not already logged-in) and then the information can be posted on the user's Facebook wall on their behalf.

The second way Facebook is used by the SciChallenge platform is by utilizing Cronjobs to automatically update the SciChallenge official Facebook page with submission information through posts in real-time. A Cronjob is a software program that functions as a time-based job scheduler. In the context of SciChallenge, a Cronjob was developed to update in real-time the SciChallenge official Facebook page with important information on SciChallenge contest submissions. In fact, the Cronjob is a scheduler that queries the platform database every 100 seconds to retrieve any new SciChallenge submissions and post an abstract of each one of them on SciChallenge official Facebook page: name of user submitting the project, title of project, format of the project (text, slides, video), time of submission, origin of submission and a brief abstract. The time interval of the updates can be modified by the SciChallenge platform administrator.

The Cronjobs are developed to continuously function as a server side PHP program; however, they run independently from the SciChallenge web platform. On the one hand, the Cronjobs are written in PHP and run on the PHP server, but on the other hand they are not served by the PHP server in coordination with the SciChallenge web platform, i.e. every time the web platform is accessed by a user. Rather, the Cronjobs utilize libraries that access operating system functionality on the server to achieve an unobstructed repetitive execution and, in this way, ensure that the Facebook updates are conducted on time.

An alternative to Cronjobs would be the SciChallenge web platform to post directly to the SciChallenge official Facebook page the submission information right after a participant submission. There are two reasons why we have developed Cronjobs to provide SciChallenge Facebook page updates: first, since the Cronjobs are independent from the SciChallenge web platform, they can be scheduled to operate at any time, according to current needs. For example, they can be scheduled to re-post submission info at any time, or post to another Facebook page as well. This makes the implementation much more flexible to suit the current needs.

Second, it provides scalability in that the Cronjobs can be extended or updated in the future by developers to process more (or less) information, or even in terms of the way they process the submission information, to enable alternative Facebook posts. For example, in the future it could be the case that "time of submission" is not important anymore to be posted on Facebook and should be replaced by "submitter information", i.e., post more information about the participant that submitted the particular project. Any such functionality updates would be feasible centrally just by re-coding only the Cronjobs.

4.2.2 Use of Twitter

Besides posting on the SciChallenge official Facebook page, the Cronjobs also use Twitter to tweet submission related information on the SciChallenge official Twitter account. The tweets occur whenever the Facebook posts occur. These tweets, although limited to 140 characters, they include submission related information, informing followers of the SciChallenge contest and web platform.

4.3 SciChallenge Widgets

SciChallenge also uses WordPress Widgets to offer to other websites the possibility to embed specific SciChallenge functionality. A widget is a small visible informational block on a WordPress website (host) that performs a specific function, e.g. visualizing countries of project submission. The web platform offers specific widgets to enable other people to embed SciChallenge functionality and/or information in their website. Such functionality may include "news" about the SciChallenge contest, information about contest participants (no sensitive information will be accessed), projects submitted, as well as information about the results of the contest, future events and links to all SciChallenge social networks and media.

As the SciChallenge Widgets are destined to be embedded in remote WordPress websites and used by these websites to access SciChallenge related information, it was important to develop a request-response SciChallenge Widgets API to handle the remote requests. The purpose of this API is, on one hand to develop this functionality in a structured and secured manner, and on the other hand to provide other external developers the opportunity to use this API to implement their own widgets or plugins to publish SciChallenge related information. Also, the API can be used to embed SciChallenge related information in non-WordPress websites - this can be done by implementing the client site request module as a separate web application.

4.4 SciChallenge Rating Module

In this section the rating module is explained in detail, since it provides a critical component of the platform that plays a key role in the evaluation of the submitted projects. The rating module uses the *Online Community Rating* followed by the *Jury Rating process*.

4.4.1 Online Community Rating

To calculate the online community rating, based on the number of "likes" and "views" a project has received online, the rating module uses the following function:

$$TS = NV + (NL \times W)$$

where $\boldsymbol{NV}$ refers to the number of "views" a project has received on Youtube (if video) or Slideshare (if poster or presentation), and $\boldsymbol{NL}$ is the corresponding number of "likes" for that project.

Since the number of views for a given submission, whether this is a video uploaded on Youtube or a poster/presentation uploaded on Slideshare, is estimated to be much larger than the number of likes (many people view the submissions but only few of them "like" them), there was a need to balance the formula so that the likes a submission receives have the same or at least similar significance as the views. This yields for a weight to be assigned to the number of likes.

As such a formula could easily become fairly complicated regarding the weights of the two factors (i.e. likes and views). Therefore, it was decided to set a constant weight $W = 3$ merely for practical and simplicity reasons, which gives a larger importance for likes based on the fact that it appreciates the project.

Specifically, due to the student audience of SciChallenge this weight was believed to provide a good balance between the two factors. More importantly, as shown in Fig. 4, it provides an easily explainable and understandable score for children that would like to monitor and trigger the progress and success of their project. In this way, if for example a submission receives 1000 views and 250 likes, then instead of receiving a total score of 1250 which would then undermine the number of likes, it receives a total score of 1750, calculating thus a more balanced result between the likes and views, as well as assigning more importance to the likes the submission has received.

Fig. 4. The social media rating of a SciChallenge project.

In order to give participants from all European countries an equal possibility to get to the second stage of the rating, avoiding thus biases based on language, the Rating Module selected the two best contributions for each participating country and for each of the categories: "age group" (1 or 2), "format" (video, poster or presentation) and "status" (individual or group). With contributions from EU-member states & Associated Countries, 193 projects reached the second stage of the rating procedure.

4.4.2 Jury Rating

The 193 projects selected by the Online Community Rating are qualified to the SciChallenge Jury Rating. The jury group consists of 39 experts on various fields and from different countries to ensure that all 10 languages (English, German, Greek, Slovenian, Czech, Hungarian, Swedish, French, Spanish and Polish) used in the projects are covered. Every project is rated by 3 jury members, all from different countries – except for language specific projects. Thus, every jury member reviews approximately 15 projects. The jury members selected the 12 best contributions, covering both age groups; individual or group contributions, as well as the three different media formats. The following criteria are used:

(A) ***Presentation of a Problem:*** the participants present or reflect on a problem in a clear manner and in a way that corresponds with the chosen format;

(B) ***Creativity of the Realization:*** the contributions are realized in a creative way;

(C) ***Added Value:*** the contributions have an added value beyond the life-time of the contest, for example to be used as inputs or examples within other settings of (formal or informal) education and science engagement;

(D) ***Future Thinking:*** the contributions aim at addressing major challenges and propose new ideas for addressing these challenges;

(E) ***Scientific Approach (only for AG2)***: The reference to and adoption of existing scientific knowledge through the participants' individual approach will be assessed.

For each criterion, the jury members allocate 1 to 10 points, which means that a contribution can reach a maximum of 40 points for AG1 and 50 points for AG2. The 12 best contributions and their winning contestants received a trip to the final Award event.

5 Evaluation Results

The SciChallenge online contest was open for submissions between 1st January and 15th May 2017. Due to age restrictions, participants younger than 15 years of age needed to register together with their parents, legal guardians or teachers. In this section at first the users' population is presented, the evaluation methodology is defined and then the analysis of the results is presented for the different dimensions considered in this study.

5.1 Population

The research study presented in this paper was applied at a Pan-European level and involved 745 students from a total of 28 countries, with a total of 437 projects (including group projects) submitted to the contest. From these projects the 204 (46.68%) were submitted to AG1 (10-14 years) and 233 (53.32%) to AG2 (15-20 years). The gender ratio in our AG1 was 35.21% males and 61.97% females, while the gender ratio for AG2 is 43.04% males and 56.96% females. In the present study, the research questions are focused on the both sample groups. A large number of students did not complete the evaluation questionnaire. Therefore, from the total of students, $N = 152$ of them are valid for analysis, adding up both $N_{AG1} = 71$) and $N_{AG2} = 81$.

5.2 Evaluation Methodology

The SciChallenge research study evaluation methodology is based along three axes: 1) platform user experience assessment, 2) STEM learning experience assessment and 3) impact of social media on attracting STEM contest participants. The first two axes are evaluated in Sections 5.3 and 5.4 using a quantitative approach based on the User Experience Questionnaire (UEQ) used in numerous studies [19], [20], [21]. Moreover, Section 5.5 presents a qualitatively assessment on the impact of social media on promoting the SciChallenge contest. Finally, the two-way ANOVA statistical analysis method is applied and presented in Section 5.6 that examines the relationship and effect of the factors of age, gender and their interaction on STEM motivation and interest.

5.3 Platform User Experience Assessment

Two simplified versions of the UEQ were prepared for the two age groups evaluated in the project. The items of the UEQs were reduced to simplify the complexity of the surveys for each group due to the fact that we are dealing with young students. The items of the UEQs are based on a Likert scale from 1 to 7.

Next, a statistical analysis of the results for both age groups is presented. Fig. 5 and the descriptive statistics in Table 2 provide a statistical analysis commonly used to describe the distribution of data for AG1. The boxplot provides a standardized way of displaying the distribution of quantitative data based on a five number summary: minimum, first quartile, median, third quartile, and maximum. The first observation is that there is a higher variation of data for Q1 (aims to assess if it is "easy to learn" how to use the platform) and Q3 (assesses if it's "clear" for the user how to use the platform).

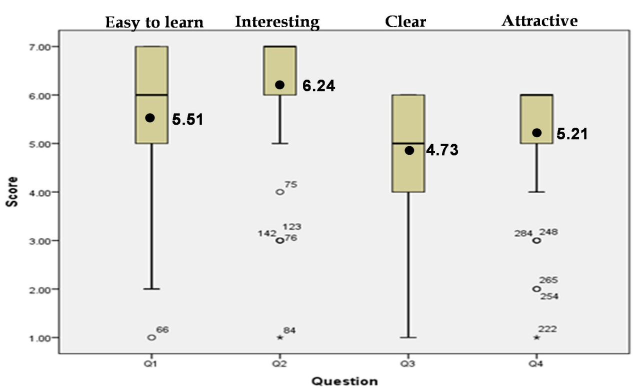

Fig. 5. Boxplot on assessing the SciChallenge platform – AG1.

In fact, distribution of the data is wider for these questions whereas Q1 ranges approximately from 5 to 7 and Q3 ranges approximately from 4 to 6. Despite the high mean values of 5.51 (Q1) and 4.73 (Q3), which show positive users opinions in terms of the platform being "easy to learn" and "clear to use", the results show that there is a higher dispersion of opinions reported by the users.

Table 2. Descriptive Statistics on platform evaluation – AG1.

Question	Q1	Q2	Q3	Q4
Mean Value	5.51	6.24	4.73	5.21
Lower Bound	**5.16**	**5.96**	**4.43**	**4.94**
Upper Bound	**5.86**	**6.53**	**5.04**	**5.48**
Median Value	6.00	7.00	5.00	5.35
Std. Deviation	**1.47**	**1.19**	**1.29**	**1.28**

*95% Confidence Interval for Mean

On the other hand as demonstrated in Fig. 5 the lower dispersion of the data for Q2 (ranges from 6 to 7) and Q4 (5 to 6), indicates that standard deviation is lower and this reflects the fact that users have a more focused opinion in terms of the fact that the platform is "Interesting" and "Attractive". The descriptive statistics shown in Table 2 also supports the above argument, with 95% confidence interval, since the difference between the lower bound and upper bound, as well as the standard deviation for Q2 and Q4, are lower than that of Q1 and Q3. This indicates that user opinions are tightly clustered together and that there is a more clear tendency and agreement in the responses for Q2 and Q4, rather than that of Q1 and Q3.

Moreover, the graph indicates that there are some outliers that refer to data points (responses) that are considered highly outside the data distribution. Finally, the negative skewness indicates that most of the data (i.e., user opinions) are on the side of positive responses, with fewer samples on the side of negative responses.

Table 3. Descriptive Statistics on platform evaluation – AG2.

Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Mean Value	6.22	5.20	6.12	5.31	5.89	6.07	5.95	6.21
Lower Bound	**6.03**	**4.78**	**5.87**	**4.97**	**5.62**	**5.82**	**5.67**	**5.97**
Upper Bound	**6.41**	**5.61**	**6.37**	**5.65**	**6.16**	**6.33**	**6.23**	**6.45**
Median Value	6.00	6.00	6.00	6.00	6.00	6.00	6.00	7.00
Std. Deviation	**0.85**	**1.89**	**1.13**	**1.54**	**1.22**	**1.17**	**1.27**	**1.07**

*95% Confidence Interval for Mean

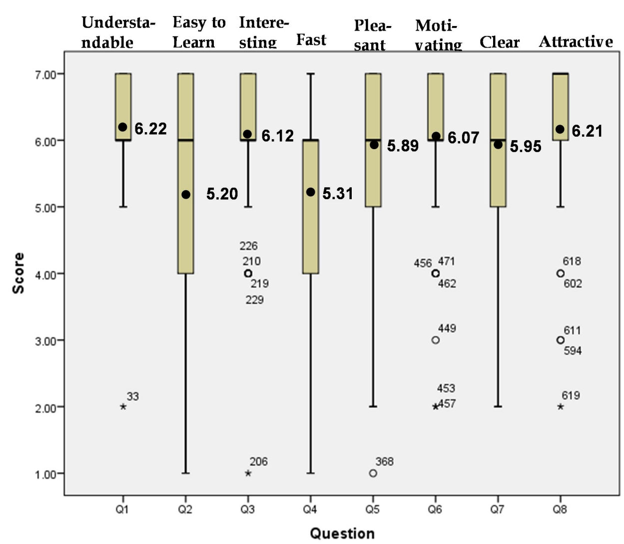

Fig. 6. Boxplot on assessing the SciChallenge platform – AG2.

Following the same reasoning as above, Fig. 6 boxplot diagrams and Table 3 descriptive statistics for AG2 reveal a stronger consensus in the users' opinions in terms of the platform evaluation for questions Q1, Q3, Q6 and Q8 rather than the rest of the questions. This means explicitly that users agree more on the fact that the SciChallenge platform is "understandable", "interesting", "motivating" and "attractive". Despite the high mean and median values that indicate positive responses to questions Q2 "easy to learn", Q4 "fast", Q5 "pleasant" and Q7 "clear" there is still a wider spread amongst the data and this reflects a higher distribution of participants' opinions.

As illustrated in Table 3, the above argument can be also supported by the lower difference between the lower bound and upper bound for the mean of questions Q1, Q3, Q6 and Q8 rather than the rest of the questions. There are also some outliers for nearly all questions in AG2 that show some entirely different opinions than the general user consensus illustrated in Fig. 6.

5.4 STEM Learning Experience Assessment

Another important aspect of the platform is to accomplish the aim of improving the learning experience of the participant in relation to STEM. Both age groups were asked to assess the STEM learning experience by answering respectively: AG1 – if they feel comfortable using the platform and if they will recommend the platform to a peer for learning about STEM and AG2 – the same as above but also if the platform had a positive impact and improved their knowledge on STEM. AG1 was asked only two questions to keep questions even simpler and understandable for the younger age group (10-14 years).

From Fig. 7 it is evident that the participants evaluated positively the STEM learning experience offered by the platform. The statistical analysis was executed for both groups with a 95% Confidence Interval for Mean.

In relation to AG1, the high mean values for the items "comfortable" and "recommend" as well as the low dispersion of data (user responses – range from 6 to 7), with only a few outliers, can be a strong measure of confidence as to positive effect of the STEM learning experience offered by the platform. In overall, AG1 has also a stronger opinion as to this positive effect.

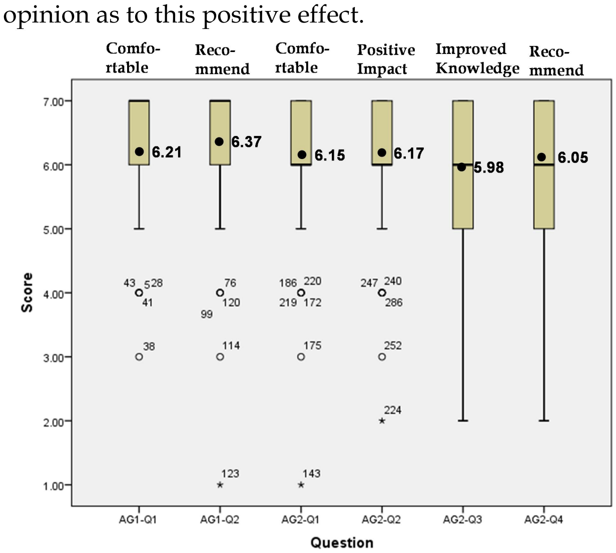

Fig. 7. Boxplot on assessing the SciChallenge STEM Learning Experience – AG1 and AG2.

A similar outcome can be observed for the items "comfortable" and "positive impact" for AG2, since a strong consensus and low variation of data can be detected in the answers of the participants (range from 6 to 7). On the other hand in terms of the items "improved knowledge" and "recommend", AG2 data spreading is greater, which clearly indicates a higher variability in terms of the data (user opinions). This can be attributed to the fact that older ages already have greater familiarity with STEM concepts and thus consider that the platform may not be of such extremely good value for peers and friends.

In overall, the above analysis, performed on the basis of a large sample of 152 participants, strongly indicates that the SciChallenge platform users valued the STEM Learning experience offered by the contest and platform, find it to be motivating and would definitely recommend the platform to their peers and friends.

5.5 Social Media Impact Assessment

The impact of Social Media followed a more qualitative evaluation method via a number of relevant questions included in the questionnaire. Therefore, these questions were not formulated using a quantitative Likert scale but were rather more qualitatively expressed. Thus, multiple selection questions with one possible answer were defined in the questionnaire. These questions were also answered by students of both age groups.

On the question "How did you experience the use of social media for engaging with other contestants and your peers about STEM", 37.8% of participants responded that the use of social media motivated them a lot to engage with other contestants and peers, 32.9% replied that the use of social media motivated them a little to engage with other contestants and peers, and 13.4% said that the use of social media did NOT motivated them to engage with other contestants and peers. A further 15.9% responded that they did not know if social media had an impact on engaging with other contestants and peers.

On how the use of social media influenced AG2 participants' experiences with STEM topics, 52.4% felt that the use of social media made STEM topics more attractive for them, while 22% felt that the use of social media did not make STEM topics more attractive for them. A rather large percentage 25.6% did not know.

On how participants in both age groups experienced the use of social media to promote their project in order to increase their chances of winning, 63.4% of AG2 participants responded that the use of social media for promoting their project was exciting and it was a positive experience for them, while 14.6% said that it was not exciting and was a negative experience for them.

Finally, regarding AG1 participants, 69.9% responded that it was exciting and a positive experience for them, while 18.8% said that it was not exciting and was a negative experience for them.

5.6. Educational Intervention and Research Design

In this section a detailed educational intervention and experimental design was followed whereby researchers conducted post-tests to study and estimate the effects of using the SciChallenge platform for participating in the contest and the STEM learning experience on the students' interest towards STEM.

5.6.1 Research Study Questions

The purpose of this experimental design is to perform an exploratory analysis of the collected data to get insight on the factors and their potential influence on the students' interest towards STEM. The factors that were taken into consideration were personal attributes collected (anonymously) during the evaluation (i.e., ANOVA analysis independent variables): students' age, gender and the factors interaction (age*gender). For each of these factors, a different research question was defined, as follows:

- ***Research Question 1 (RQ1):*** *Does the age of the students influence the effectiveness of the SciChallenge web platform and contest in increasing students' interest on STEM?*

The target population consisted of two age groups, AG1 (10-14 years) and AG2 (15-20 years), which are mainly high-school students. As existing studies [22], [23] suggest, age is an important factor and that early exposure to STEM ideas can be beneficial for future STEM development, the first hypothesis was made that age would affect participants motivation.

- ***Research Question 2 (RQ2):*** *Does the gender of the students influence the effectiveness of the SciChallenge web platform and contest in increasing students' interest on STEM?*

Furthermore, several research works [24], [25], [26] also recognise, report and discuss factors and plausible solutions to the gender imbalance in STEM fields. Hence, the second hypothesis was made that gender may well play a role in the effectiveness of our motivation-driven designed and developed STEM platform and contest.

- ***Research Question 3 (RQ3):*** *Does the interaction of age and gender has an effect on the students opinion regarding the influence of the SciChallenge web platform and contest in increasing students' interest on STEM?*

Based on the aforementioned studies and the first two stated hypotheses, the third hypothesis was made that age*gender interaction may well affect the effectiveness of the SciChallenge platform.

5.6.2 Specific Measurements and Instruments

Post-activity questionnaires included an instrument to measure the interest towards STEM. The initial survey contained some questions to collect personal factors – e.g., age, gender and country – and 6 questions for AG1 group (kept simple due to students' age) and 12 questions for the AG2 group.

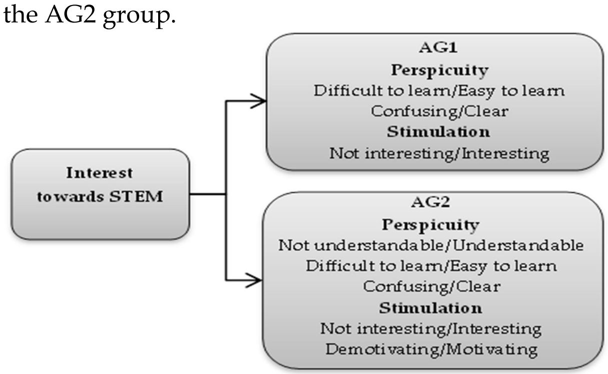

Fig. 8. Classification of the SciChallenge research study.

The *UEQ classification includes Perspicuity and Stimulation as user experience aspects* that can be associated correspondingly in this study with satisfaction in terms of the STEM learning experience and the motivation offered by the platform and contest. Hence, the following simplified *UEQ classification* is adopted in this study.

For AG1 students interest toward STEM (ANOVA analysis dependent variable) was measured using a scale composed of three 7-point Likert items (out of the 26 items of the UEQ) as shown in Fig. 8, so as to keep it simple for young participants. Thus, AG1 students were asked to:

- Rate from 1 to 7 on the three 7-point Likert items illustrated in the classification in Fig. 8. The resulting scale has a total score ranging from 3 to 21.

Also, students' interest towards STEM (ANOVA analysis dependent variable) for AG2 was measured using a scale composed of five 7-point Likert items of the adopted user experience questionnaire. Thus, AG2 students were asked to:

- Rate from 1 to 7 on the five 7-point Likert items illustrated in the classification in Fig. 8. The resulting scale has a total score ranging from 5 to 35.

Cronbach's Alpha (CA) coefficient is a measure used to assess the reliability of any given measurement and refers to the extent to which it is a consistent measure of a concept. It is a measure of internal consistency, that is, how closely related a set of items are as a group. The coefficient of reliability ranges from 0 to 1 and coefficients that are less than 0.5 are usually unacceptable.

Table 4. Cronbach's Alpha coefficient for AG1 and AG2.

Age Group 1		Age Group 2	
CA	N of Items	CA	N of Items
.598	3	.683	5

For AG1, the internal consistency of the 3-items scale used for student interest in STEM was measured using Cronbach's reliability statistics test [27], resulting in the value displayed in Table 4. The same was performed for AG2, where the internal consistency of the 5-items scale used for student interest in STEM resulted in the value displayed in Table 4. In fact, AG1 has an acceptable internal consistency ($\alpha = .598$) while AG2 reliability is at a higher level ($\alpha = .683$).

Furthermore, while the first 3 assumptions for conducting an ANOVA test were met by simple observations of the dataset, the other three assumptions namely: outliers, normality and homogeneity of variances, required additional tests. In fact, two samples (24, 35) were detected as outliers but they were retained in the dataset and not transformed as removing them did not have a significant effect on the ANOVA analysis results. Also, Shapiro-Wilk test was performed to validate data normality (*only for Age = 12.00, Gender = Female, p = .023 the null hypothesis is rejected*) and the Levene's test for homogeneity of variances also confirmed the null hypothesis ($p = .132$).

Table 5 depicts whether our independent variables (the "Age" and "Gender" rows) and their interaction (the "Age*Gender" row) have a statistically significant effect on the dependent variable, "interest in STEM". The statistical significance of the effect depends on the p-value:

- If the p-value is greater than the significance level ($p > .05$), the effect is not statistically significant.
- If the p-value is less than or equal to the signifi-

cance level ($p \leq .05$), then the effect for the term is statistically significant.

From Table 5 and in particular the "Sig." column the observation can be made that we have a statistically significant interaction at the $p = .049$ *level*. Also, we can see from the table that there was statistically significant difference in the mean interest in STEM between males and females ($p = .019$), but there were no statistically significant differences between different ages ($p < .867$).

Table 5. ANOVA Results for Between-Subjects Effects – AG1.

Dependent Variable:	**Interest_STEM**			
Source	**df**	**Mean Square**	**F**	**Sig.**
Age	4	2.409	.315	.867
Gender	1	44.599	5.829	.019
Age * Gender	3	21.182	2.769	.049

a. R Squared = .184 (Adjusted R Squared = .075)

For AG2, in regards to the last three assumptions, four samples (34, 60, 61, 69) were detected as outliers but they were retained in the dataset (removing them did not have a significant effect on the ANOVA test). Also, Shapiro-Wilk test was performed to validate data normality (*only for Age = 17.00, Gender = Female, p = .008 the null hypothesis is rejected*) and the Levene's test for homogeneity of variances also confirmed the null hypothesis ($p = .460$).

Table 6 presents the results of the ANOVA analysis that indicate clearly that neither *age, gender nor age*gender interaction* have a significant effect and that there are no differences on the interest in STEM for AG2.

Table 6. ANOVA Results for Between-Subjects Effects – AG2.

Dependent Variable:	**Interest_STEM**			
Source	**df**	**Mean Square**	**F**	**Sig.**
Age	3	2.529	.129	.942
Gender	1	44.599	.017	.896
Age * Gender	3	21.182	1.514	.218

a. R Squared = .065 (Adjusted R Squared = -.029)

6. Discussion

The aim of this section is to examine the overall motivational impact of the SciChallenge web platform in enhancing the participants' interest in STEM. Hence, in this section, the results are discussed and interpreted in regards to how these help answer the research questions defined in subsection 5.6.1.

RQ1: No, for both age groups. As we hypothesized, the results showed no evidence that age affects the platform motivational aspects and its offered learning experience effectiveness. We are aware that some authors argue that learners' age is one of the parameters influencing the effectiveness of platforms and contests for STEM-learning [28], [29]. That is not the case in this study, perhaps because the platform was specially conceived for the ages of 10-20 and the students who participated in the study fit the intended audience. This applies to both age groups.

RQ2: Yes for AG1, but this is not true for AG2. In fact, the claim can be made (on the basis of the ANOVA results) that gender plays a role at younger ages (10-14) in terms of the opinion on the impact and effectiveness of the platform. The participants in AG2, irrespective of gender, have perhaps an already established understanding and/or excitement for STEM and thus no significant deviations were documented (*Male Mean = 29.328, Female Mean = 29.479*). In terms of AG1, a considerable difference is shown and this demonstrates that gender had an effect in this group (*Male Mean = 16.340, Female Mean = 18.692*).

A plausible explanation is less excitement and interest for female participants in later ages, which is attributed also in analogous studies. Specifically, in [30] authors explicitly state: "Results showed a significant association of students' programming involvement with their motivation to learn more programming. Interestingly, in the youngest groups/entry-level competitions, girls were heavily involved in programming. Unfortunately, in older/more advanced competitions, girls were generally less involved in programming, even after controlling for prior programming experience. These gendered effects were substantially explained by programming interest."

RQ3: Yes for AG1, but this is not true for AG2. In light of the ANOVA results in Tables 5 and 6, we can claim that *age*gender interaction* effect is evident for AG1 but not for AG2. This can be attributed to the strong effect that gender has for AG1 as observed in RQ2 of this study.

7 Conclusions and Future Work

The SciChallenge is a pan-European contest and aims for a broad participation of children, teenagers and young adults of both genders from all EU-member states and associated states. One of the main aims of the contest is to boost the interest of these persons in STEM. Hence, the SciChallenge web platform was designed and developed for youngest groups, taking into consideration their needs and requirements. Due to the heavy engagement of youngsters with social media the platform offers mechanisms to ensure that their competition activities can be easily exposed to other peers.

The main purpose of this study was to evaluate the overall opinion of users on the platform and the offered user learning experience and motivation towards STEM (quantitatively) and the impact of social media (qualitatively). In fact, the large number of participants (745) and more especially the fact that female participation (419) outweighs male participation is another important success factor of this work, since gender imbalance is still considered a big issue in STEM subjects and careers [24], [25], [26]. More interestingly, the study further explores the factors of *age, gender and age*gender interaction* and their effect on the educational outcomes produced by the SciChallenge platform designed to improve the interest in STEM for children of ages 10-20.

The results indicate that *gender and age*gender interaction* are the factors affecting the interest in STEM generated by participating in the SciChallenge contest, only for earlier ages (AG1). Specifically, the gender influence was even stronger than the effect found from the age*gender interaction even for AG1. The present study can therefore claim that early age educational interventions are particularly constructive and beneficial for females.

More to the point and as defined in many research works, this study revealed that while competition experiences may motivate all students to learn more about STEM, the SciChallenge educational intervention showed higher motivation, excitement and interest for female participants in early ages. This has the capability to shape their choices that currently are restricted by cultural barriers, gender stereotypes, or misinformation, as attested in [24]. Hence, early intervention may well play a role in shrinking the gender gap in STEM fields, and opportunities for girls to realize their full potential in math and science should increase. This point requires an even more explicit examination and exploitation in future work.

ACKNOWLEDGMENT

SciChallenge has received funding from the EU Horizon 2020 Research and Innovation Programme under Grant Agreement No 665868.The authors are grateful to all participants of the contest, the project consortium members, the jury members and supporters as well as to all schools and teachers involved in this experiment.

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