Geoquest Project Implementation and Experimentation of a Computer Classroom Role Playing Game: Final Results

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Abstract

The GeoQuest Project started as a PhD research project in Teaching and Learning Processes in Science Education. It aims to answer to both students and teachers' needs in an ever-changing world. Today, in particular, students need teaching tools that use different communication codes, as they are less accustomed to abstraction. An increasingly interconnected and technological world requires students to have specific skills: knowledge of the disciplines founding cores in an interdisciplinary key is required, along with technical and technological skills, mastery of foreign languages, flexibility, attitude to team working, creativity and entrepreneurship. Scientific subjects, such as Science, Technology, Engineering and Mathematics (STEM subjects) need to be strengthened and studied through a laboratory approach. On the other hand, teachers need user-friendly teaching tools, which allow and promote teamwork, which allow the laboratory teaching and the CLIL (Content and Language Integrated learning) approach. We have therefore developed a Computer Classroom Role Playing Game (CCRPG), GeoQuest, which has already been described in some international publications; a multi-phase experimentation was carried out for two years.

In this paper, we illustrate the phases of experimentation, the excellent results achieved and the quantitative statistical analysis.

The final outcome is how GeoQuest Project matches the students and teachers' needs.

Keywords: Digital Game, Learning on Gaming, Science Education, Earth Sciences, Teaching Methodology

Introduction

Nowadays, globalisation in an increasingly interconnected and technological world requires people to have specific skills: knowledge of the disciplines founding cores in an interdisciplinary key is required, along with technical and technological skills, mastery of foreign languages, flexibility and ability to reconvert, attitude to team working, creativity and entrepreneurship.

Furthermore, there is an education inequality, in Europe and in the world, especially in scientific topics, which has required repeated interventions to promote the STEM disciplines and a suitable training in Science and Technology. Therefore, teachers training and renovation efforts were also necessary to support the methodological change and to obtain the foreseen results. However, these interventions have not always achieved their goal: on the one hand, teachers seem to be resilient to change, on the other hand they ask for innovative yet convenient tools.

The aim of this work is to prove that it is possible to reconcile the needs of teachers to have user-friendly teaching materials to the needs of students to have effective training. GeoQuest Project can be a good solution, not only for teachers, but also for students, as it is able to guarantee an effective acquisition of the key competences and the disciplinary ones of Science and Technology. The results obtained confirm this is actually possible.

Theoretical Background and State of the Art

The education guidelines, focused by the EU Commission, are perfectly in line with the world's leading educational instances: innovative teaching, Information and Communications Technology (ICT), hands-on activities, lab activities, etc. An innovative teaching technology combines ICT, traditional and modern media, and social networks, where gaming is a key element. (Maraffi, Paris & Sacerdoti, 2017). Chapman and Rich (2017) claimed that games might encourage students to spend more time studying, be more engaged, and as a result, learn more. This new way of learning offers new opportunities to use collaborative tools, allowing the students to co-construct knowledge efficiently (González et al., 2016). Results indicate DGBL (Digital Game Based Learning) increases student motivation to pursue geoscience learning (Bursztyn et al., 2016). "The innovative practices are driven by champion teachers, those that are willing to go one step beyond in the benefit of their students. School's strategies are, in general, very exam oriented and have to handle lots of bureaucratic work." (Doran et al., 2016). Therefore teachers need to improve their ICT (Information and Communication Technologies) skills and their mastering of interactive teaching applications; they are also aware that the actual availability of

structured teaching materials is poor and unsatisfactory (Maraffi & Sacerdoti, 2016 b).

Identification of teachers' needs

Preliminary step: impact of the methodological reform

In the initial phase of the research, interviews were conducted with teachers to collect the actual and perceived needs for the implementation of innovative teaching methods. The sample interviewed consisted of 120 teachers: 40 from primary schools, 40 from secondary schools (first grade, consisting of 11-14-year-old students) and 40 from high schools. The questions expected an affirmative or negative answer. Questions posed and the results, expressed as a percentage, are summarised in Table No. 1. While an in-depth analysis of all answers we can summarise the obtained results as follows:

- In general, teachers consider positively the incentive towards methodological innovation, though with some reservations. They believe this innovation could require teacher training through refresher courses, but not all of them would be available to undergo the update voluntarily. Here a series of factors intervene, among which the workload to which the teachers are subjected and the attitude to question themselves.
- Regarding new technologies, teachers feel adequately prepared themselves to provide students scientific skills required by modern society. Given the choice, they would not undergo refresher courses on ICT (Information and Communication Technologies); majority of them do not use computer tools, neither for professional updating, nor for communications (email, etc).
- Teachers, as for requests to use a new methodological approach, such as CLIL (Content and Language Integrated Learning) and as teaching planning and skill assessment, believe they are not appropriate to support them. They assert that, especially for the CLIL, although prepared and certified by MIUR refresher courses, foreign language learning requires the linguistic mastery exclusive to mother tongue teachers, or at least to the teachers dedicated to this professional purpose.

Table 1. First step teachers' survey: interview about innovative teaching implementation.

	Questions							*Ave* *Yes*	*Ave* *No*
		Yes	*No*	*Yes*	*No*	*Yes*	*No*		
	Do you think the propulsion towards a methodological innovation in teaching is positive?	72	28	65	35	57	43	64,7	35,3
	Do you feel adequate to use of new teaching methods?	16	84	29	71	34	66	26,3	73,7
	Do you think that with the teacher training courses you can change the way they teach?	75	25	61	39	52	48	62,7	37,3
	Are you willing to take refresher courses to improve your professional skills?	66	34	55	45	41	59	54,0	46,0
	Are you willing to take refresher courses to improve your students' learning outcomes?	66	34	53	47	31	69	50,0	50,0
	Do you consider your preparation adequate to provide your students with the scientific skills required by the current world?	45	55	69	31	83	17	65,7	34,3
	Are you willing to update yourself to effectively use IT tools in teaching?	32	68	29	71	18	82	26,3	73,7
	Are you willing to update yourself to effectively use IT tools in your professional practice?	25	75	20	80	13	87	19,3	80,7
	Do you regularly use your email for your work communication?	15	85	33	67	41	59	29,7	70,3
	Do you regularly use the web to keep yourself professionally updated?	19	81	26	74	61	39	35,3	64,7
	Do you think you are able to apply the CLIL approach to your teaching?	5	95	11	89	18	82	11,3	88,7
	Do you think that the linguistic competence of a teacher of other discipline can be effective in learning a foreign language?	2	98	3	97	7	93	4,0	96,0
	Do you think work in the classroom with more teachers in team working is effective?	69	31	24	76	19	81	37,3	62,7
	Would you like innovative learning materials that are easy to use?	85	15	83	17	86	14	84,7	15,3
	Would you like innovative teaching materials that provide the possibility of an authentic evaluation?	91	9	88	12	72	38	83,7	19,7

• Among the issues discussed with the teachers, it was decided to focus on three questions, results of which are shown in the diagrams in Figure No. 1. Teachers believe that they are poorly suited to the use of new teaching methods (Figure No. 1a, b, c), but are not willing to voluntarily undergo

refresher courses, especially on use of ICT in teaching (Figure No. 1d, e, f). On the other hand, they would rather appreciate innovative teaching material already structured and easy to use (Figure No. 1g, h, i).

Data collected in this first research step were used to calibrate technical-methodological characteristics of GeoQuest Project, taking the main teaching and educational needs perceived by teachers into account. Keep in mind that GeoQuest Project was born as an educational innovation tool, to improve Science students' learning (Maraffi & Sacerdoti, 2017), Science and Technology skills obtainment (Maraffi & Sacerdoti, 2016 a), and to enhance key competences of citizenship (Maraffi, et al., 2016). In fact, teaching materials must be adapted to teachers needs and must be user friendly, to obtain more effective learning results.

Intermediate step: innovative methodologies mastery

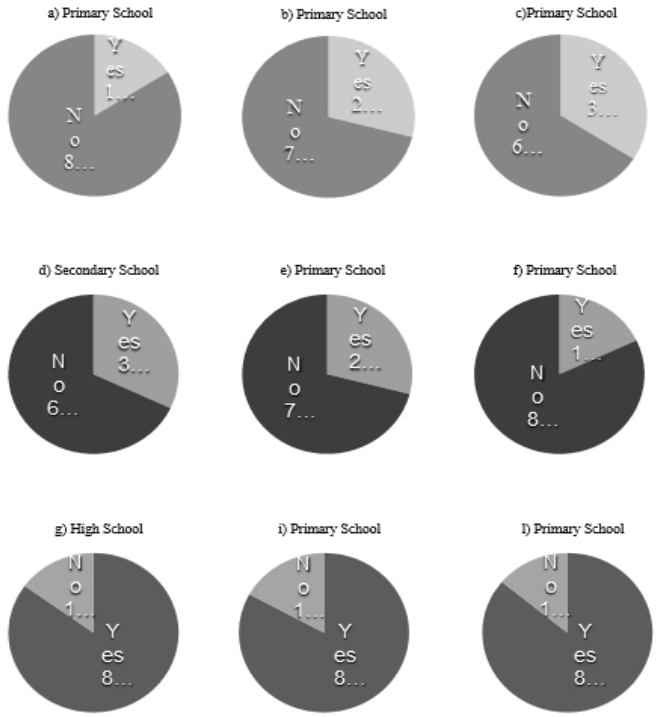


Figure 1. Answers of teachers (a,d,g: primary school; b,e,h: secondary school; c,f,i: high school) to three significant questions. a, b, c: "Do you feel adequate to use of new teaching methods?"; d, e, f: "Are you willing to update yourself to use IT tools in teaching?"; g, h, i: "Would you like innovative learning materials that are easy to use?".

In a second research step, a sample of 22 teachers (all grades of school, teaching different subjects) was analysed. Teachers voluntarily participated in a refresher course in "Innovative teaching methodologies and

digital teaching". In this case, to participants were asked to express a numerical evaluation - on a scale of 1 to 10 - about 20 questions. Results are collected in Table No. 2, and show that:

Table 2. Second step teachers' survey: perception of teachers' teaching skills.

Questions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Ave
Own pedagogical skills satisfaction	8	7	8	5	7	7	5	5	7	5	5	8	6	6	7	6	7	7	8	6	6	8	**6,5**
Knowledge of modern teaching methods	7	7	9	5	6	7	5	5	7	5	5	7	5	5	5	5	8	8	8	5	5	7	**6,2**
Use of varied teaching methods	7	7	9	5	6	8	6	6	6	6	6	7	7	7	7	7	7	7	7	7	1	7	**6,5**
Easy to find educational materials on the web	6	7	7	5	8	7	6	7	7	6	6	8	8	8	8	9	9	9	9	7	4	5	**7,1**
Use of web educational materials	7	6	7	7	9	8	5	7	7	6	6	9	8	8	8	9	10	10	10	5	4	6	**7,4**
Use of a Multimedial Blackboard as projector exclusively	7	6	5	7	5	6	5	2	7	2	2	6	8	7	7	9	1	1	1	4	4	7	**5,0**
Multimedial Blackboard software mastery	5	6	5	5	7	5	5	5	6	2	2	7	5	5	5	8	1	1	1	5	5	5	**4,6**
Use of PC for teaching	5	6	9	5	8	6	5	6	6	6	6	8	4	4	8	9	10	10	9	5	5	5	**6,6**
Use of tablet for teaching	5	6	9	2	7	6	6	2	6	6	2	9	2	3	8	4	10	10	9	5	4	5	**5,7**
Need to change teaching method	8	7	5	5	6	7	6	6	7	6	6	9	7	7	8	6	7	7	7	6	5	8	**6,6**
School website easy use for institutional purposes	8	8	8	4	6	7	6	6	7	6	5	7	9	9	8	6	8	8	10	7	5	8	**7,1**
Email easy	7	8	8	4	8	8	7	7	7	6	6	7	9	9	7	9	10	10	9	6	7	7	**7,5**

Table 2. Second step teachers' survey: perception of teachers' teaching skills.

Questions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Ave
use for institutional purposes																							
Riesco a conservare facilmente il materiale didattico da me preparato	5	6	7	7	8	6	7	7	8	6	6	9	8	8	8	9	9	9	9	7	7	5	**7,3**
Mi servo di vocabolari, dizionari, traduttori disponibili in rete	7	7	9	7	9	6	7	7	7	7	6	9	10	10	8	9	9	10	10	8	7	6	**8,0**
Prediligo le presentazioni multimediali	5	7	7	5	8	5	6	7	6	6	6	9	5	5	6	5	9	10	9	5	4	4	**6,3**
Mi servo spesso di materiale audio e/o video per la didattica	7	7	7	5	7	6	6	5	5	7	6	8	5	5	8	9	10	10	10	5	5	7	**6,8**
Sento la necessità di mantenere sempre un approccio laboratoriale	5	8	9	5	7	5	6	6	6	6	6	9	5	5	7	7	9	9	9	7	5	7	**6,7**
Utilizzo i social network	8	8	5	5	7	5	6	7	6	6	6	6	9	9	7	8	10	10	9	8	7	8	**7,3**
Utilizzo l'approccio ludico nella didattica	7	8	10	5	7	8	6	7	7	7	7	8	5	5	7	9	10	10	9	9	7	7	**7,5**
Mi è facile valutare le competenze	8	7	10	5	6	7	8	6	7	6	6	7	7	7	6	8	8	7	8	8	7	8	**7,1**

- among few teachers who would train themselves to innovate their teaching methodologies (Figure No. 2), the web and teaching materials are used rather frequently (votes around 7/10). Web in particular is mostly used for translators and vocabularies (8/10). The perception of teachers' pedagogical skills and the mastery of innovative teaching methods is only sufficient (6/10), while laboratory approach is somewhat higher (6.7/10). The

use of technological tools in teaching is mediocre, such as multimedia blackboards (5/10) and tablets (5.7/10), while the mastery of software utilisation is definitely insufficient (4.6/10).

Table 3. Third step teachers' survey: interview about innovative teaching implementation.

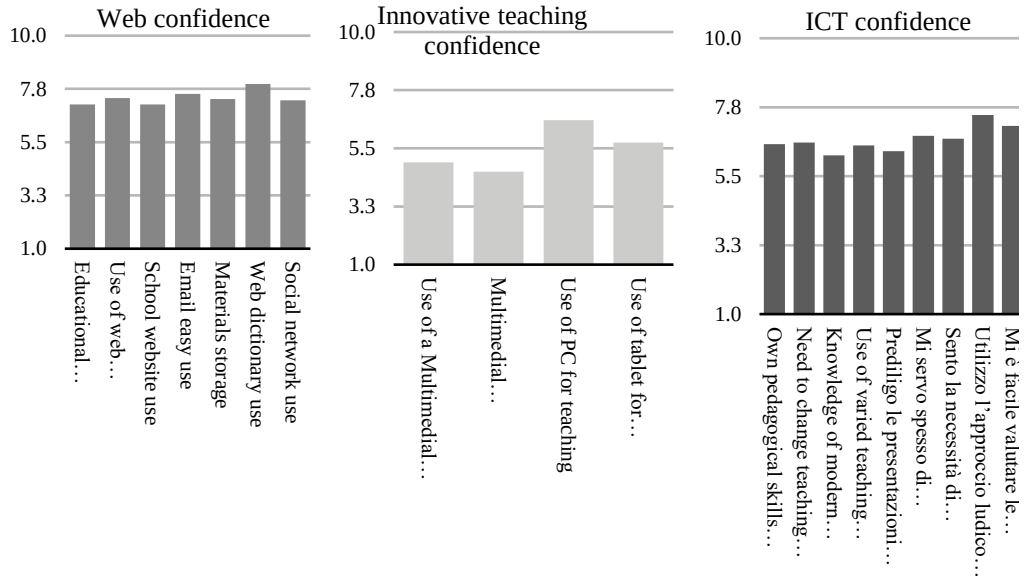


Figure 2. Web confidence, Innovative teaching confidence and ICT confidence, measured on teachers sample of survey 2.

Final step: teachers' needs

Questions	Yes	No
Do you feel adequate to use of new teaching methods?	27,4	72,6
Are you willing to update yourself to effectively use IT tools in teaching?	19,1	80,9
Would you like innovative learning materials that are easy to use?	89,3	10,7

Subsequently, a third phase of investigation with teachers was carried out. In this case, the survey sample consisted of 439 teachers participating in the compulsory refresher courses required by the three-year MIUR update plan[1]. Within this sample 154 teachers followed the refresher courses in

[1] National Plan for teacher training 2016/2019, D.M. 797 of 2016

Didactic Planning of Sciences for Skills, and 285 teachers followed the course of approach to CLIL. Results of the third survey are summarised in Table No. 3. We can note that the needs of the teachers less interested in updating and professional improvement are the same as those of the first survey (Figure No. 3), as the requests of the Ministry of Education, of society, of the whole

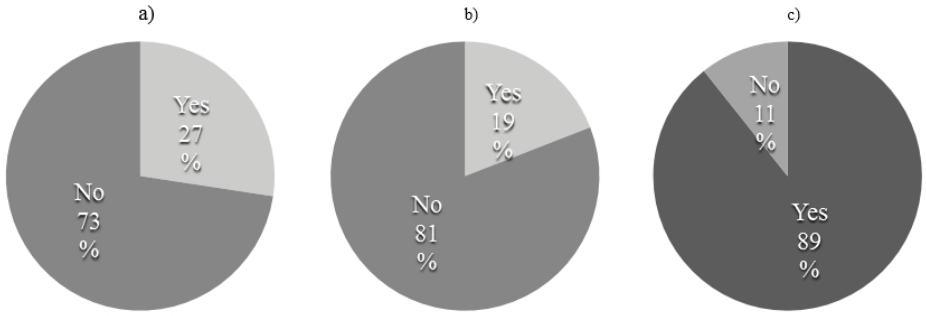


Figure 3. Adequacy of teachers about new teaching methods (a), will to attend refresher courses (b), innovative teaching materials need (c), measured on teachers' sample of survey 3.

world, force them to apply teaching methods consistent with a changing world. Summarising, from our surveys, we can highlight these specific teachers' needs (Table No. 4):

Table 4. Teachers' needs: to have teaching materials with specific features

	Features
1	Structured
2	User-friendly
3	Innovative
4	Interdisciplinary
5	Multilingual
6	Immersive learning environment
7	Skills authentic assessment
8	ICT provided
9	Engagement

• to have well-structured, user-friendly teaching materials available. These innovative teaching materials must also allow an interdisciplinary and multilingual approach (CLIL approach), and must develop a learning environment allowing an effective skill assessment.

• to have teaching materials that use ICT (to enhance the digital competence) and that ensure an effective student engagement.

Methodology

Table 5. GeoQuest'Project features

Characteristics	CCRPG
Immersion	Narrator speaking voice, sounds effects, photo, original designs, and musics, create a totally immersive environment.
Engage	Thanks to storytelling, mystery, and suspense.
Changing environments	Adventure pathways change depending on the players' choices.
Mystery	Each path may have a different finish andfantasy is blended with real world.
Shared experiences	All players follow game on the same multi-medial whiteboard or other screen.
Cooperative learning	Shared experiences foster cooperative learning.
Lab	Possibility to have lab activities or watch related videos.
Immediate feedback	Game engine indicates immediately whether the answer provided by the player is correct or wrong. In the latter case, the exact answer is indicated.
Interactivity	Players interact with the game trough their own smartphones or tablets, using a LAN.
Inter-disciplinarity	Science topics are treated with humanities.
Multi-language	Adventures pathways available in any language.
Inclusion	Accessible design creates an inclusive educational environment: different communication codes (video and audio), notebooks
User friendly	Software is specific for this CCRPG and it can also be used by non-experienced teachers.

As already mentioned above, we have taken into account the specific needs of teachers, as we consider essential for them to be able to work in fulfilling conditions, in order to maximise the effectiveness of the teaching action. We have therefore developed a Computer Classroom Role Playing Game (CCRPG): GeoQuest (Maraffi, Paris & Sacerdoti, 2017), the characteristics of which are summarised in Table No. 5. For a detailed description of the GeoQuest Project (disciplines, languages, learning paths,

etc.), please refer to the bibliography. Table No. 6 indicates the educational goals and the corresponding strategies adopted in the GeoQuest game.

Table 6. Educational goals and corresponding CCRPG (Computer Classroom Role Playing Game) strategies

Educational Goals		CCRPG Strategies	References
Engaging		Digital storytelling	Maraffi, S., Scamardella, A. (2016).
		Use of smartphones and tablets	Sacerdoti, F.M. & Maraffi, S., (2015).
		Sound effects, videos, etc	Maraffi, S., Pennesi, D., Acqua, A., Stacchiotti, L., Paris, E. (2016).
Immersive learning environment		Photos, videos, pictures, sounds	Maraffi, S. & Sacerdoti, F.M. (2017).
Key competences improvement	Communicating in a mother tongue and Communicating in a foreign language	Multilingual	Maraffi, s. & Paris, E. (2017).
	Scientific and technological competence	STEM[1] topics	Maraffi., S. & Sacerdoti, F.M. (2016a).
	Digital competence	Digital tool	Maraffi, S., Paris, E. & Sacerdoti, F.M. (2017).
	Learning to learn	Inquiry approach and immediate feedback	
	Social and civic competences	Team working and cooperative learning	
	Sense of initiative and entrepreneurship	Problem solving	
	Cultural awareness and expression	Interdisciplinarity STEAM[2] & SSH[3]	Maraffi, S., Scamardella, A. & Sacerdoti, F.M. (2016).
Autentic skills assessment		Interdisciplinarity	Maraffi, S., Sacerdoti, F.M. (2016b).
		STEAM[2] approach	Maraffi, S. & Sacerdoti, F.M. (2017).
		Achievable tasks	Maraffi, S., Marinelli, A.L. (2016).
CLIL approach		Multilingual, with virtual mother tongue voices	Maraffi, S., Ercolino, I. & Sacerdoti, F.M. (2017).
BES		Notebooks, as compensatory tools; audio, video subtitles as dispensative measures	Maraffi, S. & Sacerdoti, F.M. (2017).

[1] Science, Technology, Engineering & Math
[2] Science, Technology, Engineering, Art & Math
[3] Social Sciences and Humanities

The aim of the experimentation is to demonstrate that GeoQuest match the desired characteristics: improving learning and satisfying the teaching needs.

Experimentation

First experimental test: calibration (Maraffi, Paris, & Sacerdoti, 2017)

A first experimental test (Maraffi & Sacerdoti, 2016 b) was carried out with the aim to:

A. Calibrate and evaluate the impact and effectiveness of our CCRPG methodology in order to make all the necessary changes to the learning environment: software characteristics, player interactions, game features, and enhancements to the stories already completed (processing and improvement step);

B. Verify applicability in different situations, school types, class types, and student ages;

C. Develop a rigorous experimental protocol to be used in the final phase of the experimentation;

D. Perform a first qualitative experimentation.

Table 7. GeoQuest adventure pathways

	Adventure pathway	Students' age	References
1	SoilQuest	8-12	(Maraffi et al., 2016a, 2016b)
2	GeoQuest Hawaii	10-18	writing
3	Geoquest Phlegrean Fields	13-18	(Maraffi, Scamardella, & Sacerdoti, 2015)
4	GeoQuest Vesuvius	17-21	(Maraffi, Sacerdoti, & Scamardella, 2016)
5	CrimeQuest	17-21	(Maraffi, Ercolino & Sacerdoti, 2017)

A first interesting result is highlighted by the pie graphic

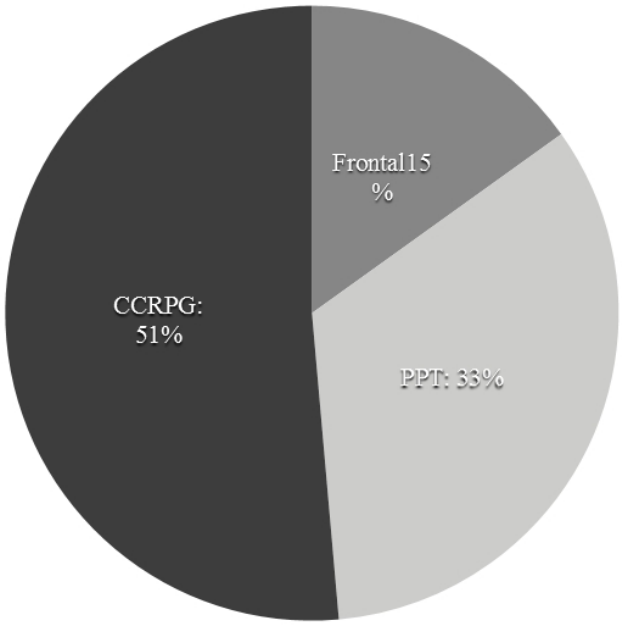


Figure 4. Students approval of three different teaching methodologies: CCRPG, PPT supported lesson, and traditional (frontal) lesson.

representation of the overall student approval average in Figure No. 4 about teaching methodologies. In the evaluation, we considered participation, comprehension, ability to convey complex topics and ability to learn a foreign language (Maraffi & Sacerdoti, 2016 b). Five different adventure pathways have been realised, related to different students' ages (Table No. 7). GeoQuest Project experimentation with younger students was evaluated based on authentic evaluation tests and was definitely satisfying. Students, aged 8-10 and 11-12 years, experimented the SoilQuest pathway; while students, aged 13-14 years, the GeoQuest Phlegraean Fields one. For an accurate description, refer to the bibliography (Maraffi et al, 2016; Maraffi & Sacerdoti, 2016 b).

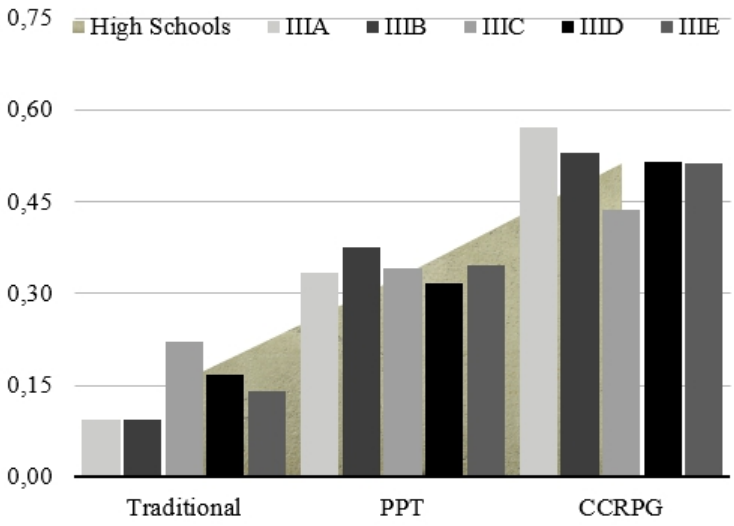


Figure 5. Teaching methodologies' outcomes of 5 secondary school's classes and of high school's average

In Figure No. 5 we showed the adventure outcomes results of five secondary school classes (13, 14-year-old), compared to high school classes average result. We can see that results obtained are in line with those of high school students, sometimes even higher. Yet the proposed adventure path was rich in elements of mineralogy, as well as of volcanology and geology.

Figure 6a. Students'engagement about GeoQuest Project.

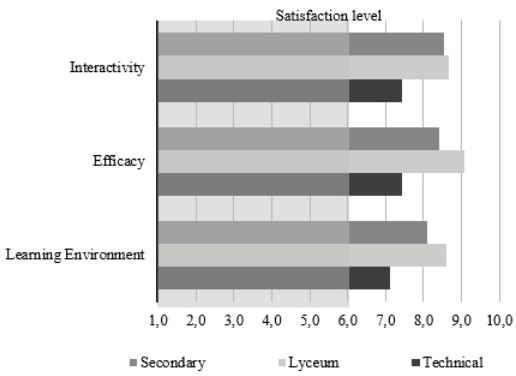
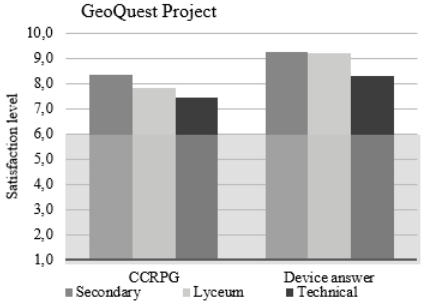


Figure 6b. Customer satisfaction about GeoQuest Project



This means that the mixture of scientific and humanistic elements (myth, history, etc.), conveyed by digital storytelling, is even able to acquire skills in complex subjects. Figure No. 6 shows the GeoQuest Project, Phlegraean Fields pathway appreciation results. This path is the richest in terms of mineralogy and crystallography elements. Phlegraean Fields is a volcanic Campania area site and it is unique in the world as it is rich in volcanological and geological elements consistent with the rich mythology of the place. It is

evident that the feedback is quite above sufficiency, regarding both interactivity and experience effectiveness, both for learning environment (Figure No. 6a). In particular, students' satisfaction exceeds the "Good" evaluation of Computer Class Role Playing Game (CCRPG) and answer devices (smartphones and tablets), as shown in Fig. No. 6b.

Experimental observation evidences show that CCRPG seems to be one of the most effective game based learning typology to improve student learning. Digital storytelling enhances student engagement, in agreement with Akkerman, Admiraal, and Huizenga (2009) which found that storifying history using mobile games had a positive effect on student engagement. Figure No. 7 (Maraffi & Paris, 2017) showed that attention rate for frontal lesson and the one related to the multi-media lesson are similar. Multi-media activities (PPT supported) allow only a degree of attention slightly larger. This may be multi-media tool contribution, which increases the perception. Student's perception increases but it has same small attention duration and same drop out. Instead, the CCRPG allows a significantly greater attention, with a persistent attention during the whole game.

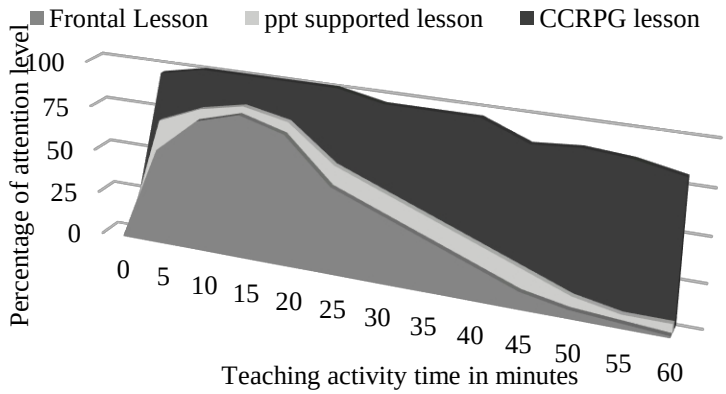


Figure 7. Percentage of attention level measured after frontal teaching activity (grey), after multimedia teaching activities supported by Power Point (light grey) and after GeoQuest teaching activities (dark grey). Average calculated on 26 classes.

Final experimental test: definitive quantitative experimentation and data analysis

In a second step a definitive quantitative experimentation is been executed, followed by the data analysis. CCRPG GeoQuest has been experimented in different classes, using a personal computer and a multimedia Interactive Whiteboard (IWB). Students were able to interact with the game through their own smartphones or tablets with a simple

browser connected to game via LAN (Local Area Network). The total research sample consisted of 40 classes, from primary schools to university, for a 914 total students. Within this sample, 32 classes (731 students) have experimented with the CCRPG and 8 classes (183 students) had a traditional lesson: frontal lesson, supported by interactive multimedia whiteboard, with photos and videos. The control groups' lessons had same duration and same contents as those of corresponding experimental samples. Research population's features are summarised in Table No. 8. In Table No. 9 classes submitted to second experimentation step are indicated. These experimental groups have performed the definitive quantitative experimentation, for a 380 total students (303 students with CCRPG, 77 students as control group).

Table 8. Research population's features

Classes	Students' age	School's kind	CLIL approach	Special Educational Needs	Adventure pathway	Note
4	8-10	Primary		X	SoilQuest	
1	8-10	Primary				Control group
3	11-14	Secondary		X	SoilQuest	
1	11-14	Secondary				Control group
5	13-14	Secondary		X	GQ Phlaegrean Fields	
1	13-14	Secondary				Control group
2	16-18	High		X	GQ Phlaegrean Fields	
1	16-18	High				Control group
4	14-16	High	X	X	GQ Phlaegrean Fields	
6	16-18	High	X	X	GQ Vesuvius	
1	16-19	High	X		GQ Vesuvius	Iceland group
1	14-19	High	X			Control group
2	16-18	High			GQ Vesuvius	
1	16-18	High				Control group
2	17-18	High	X		CrimeQuest	
1	17-18	High	X			Control group
2	14-17	High		X	GQ Hawaii	
1	14-17	High	X			Control group
1	20-22	University			GQ Vesuvius	
40						

	Table 9. Quantitative experimentation sample's features					
Classes	**Age**	**School's kind**	**CLIL**	**SEN**	**Adventure pathway**	**Note**
6	16-18	High	X	X	GQ Vesuvius	
1	16-19	High	X		GQ Vesuvius	Group from Iceland
1	16-19	High	X			Control group
2	16-18	High			GQ Vesuvius	
1	16-18	High				Control group
2	14-17	High		X	GQ Hawaii	
1	14-17	High				Control group
1	20-22	University			GQ Vesuvius	
15						

Recent findings

Data processing To evaluate the learning outcome, students were given a pre-test and a post-test, with same questions. Ten questions referred to the main contents conveyed by didactic activity in order to test both knowledge and skills. Furthermore, post-test surveys were conducted on students and teachers, about customer satisfaction.

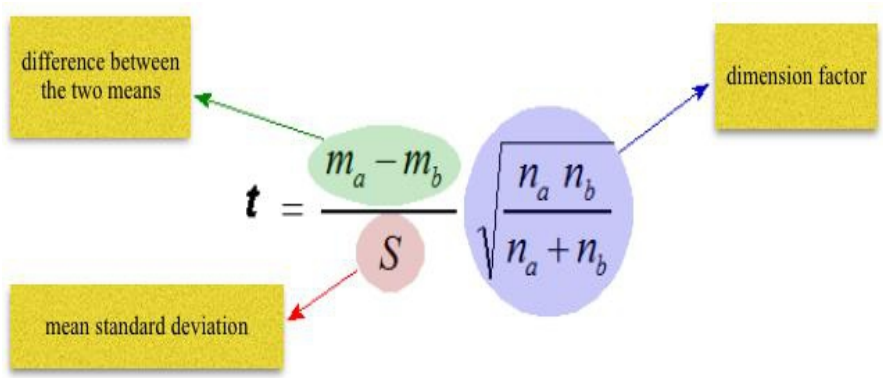


Figure 8. Formula for calculating the value t

The data obtained were submitted to student test (Figure 8), to determine if the two sets of data were significantly different from each other. First data set was pre-test results, the second one was post-test results. The t-test also tells us how significant differences are; in other words it lets us

know if those differences could have happened by chance only or not. Every t-value has a p-value to go with it. A p-value is the probability that results from your sample data occurred by chance. P-values are from 0% to 100%. They are usually written as a decimal number. For example, a p-value of 5% is 0.05. Low p-values are good; they indicate our data did not occur by chance. For example, a .01 p-value means there is only a 1% probability that the results from an experiment happened by chance. In most cases, a 0.05 (5%) p-value is accepted to mean data is valid (Park, 2005).

Table 10. P-values for experimental samples

Class	Dataset	1	2	*t*	*P-value*
Comenio IV I	**Media**	1,3333	3,6667	***5,4377***	**0,0000083929**
	Standard dev.	1,2344	1,1127		
Comenio IV G	**Media**	2,1818	3,8636	***3,9474***	**0,0002952798**
	Standard dev.	1,5318	1,2834		
Mazzini V D	**Media**	0,2500	3,0625	***6,5733***	**0,0000002843**
	Standard dev.	0,5774	1,6112		
Mazzini V A	**Media**	2,2083	5,0833	***7,2091***	**0,0000000044**
	Standard dev.	1,5030	1,2482		
Mazzini V I	**Media**	2,4800	4,1200	***5,2352***	**0,0000036020**
	Standard dev.	0,7141	1,3940		
Mazzini V C	**Media**	0,9600	6,0400	***11,0020***	**0,0000000000**
	Standard dev.	0,7895	2,1695		
Comenio V H	**Media**	1,9130	4,8261	***5,9053***	**0,000000465**
	Standard dev.	1,6491	1,6963		
Comenio V E	**Media**	1,0526	3,7368	***6,7160***	**0,0000000777**
	Standard dev.	1,1773	1,2842		
Kvennaskólinn í Reykjavík	**Media**	1,5000	4,3333	***5,5241***	**0,0000035797**
	Standard dev.	1,2948	1,7489		
Galilei	**Media**	0,6000	6,1333	***13,1235***	**0,00000000000017**
	Standard dev.	1,2984	0,9904		

In Table No. 10 the P-values calculated for the experimental groups are indicated: it is clear that our experimental data are more than acceptable, as the probability that the obtained results are due to chance is practically nil.

Experimental results

In Figure 9 pre-test and post-test results of the last experimentation phase are shown. Figure 9 a-g refers to the class groups that have experimented CCRPG with CLIL approach, while figures 9 h,i and 9 l,m show results of groups that have experimented with the CCRPG in their mother tongue (Italian). It should be noted that these quantitative results refer to a measure and not to an evaluation, so that no other parameter of

evaluation may diminish, invalidating the comparison. We compared the number of correct answers provided to the

Table 11. Media, median and mode values for relative frequency of exact answers provided in the pre-tests and post-tests.

	Pre-tests	**Post-tests**
Media	1,6	4,4
Median	1	4
Mode	1	5

same test, to questions proposed both immediately before and immediately after the experience with the CCRPG GeoQuest. The measurement of learning level is indicated on the Y-axis while on the X-axis student's order numbers are indicated, i.e. those corresponding to class diary. It is evident in all class groups post-test measurements are clearly higher than pre-test measurements.

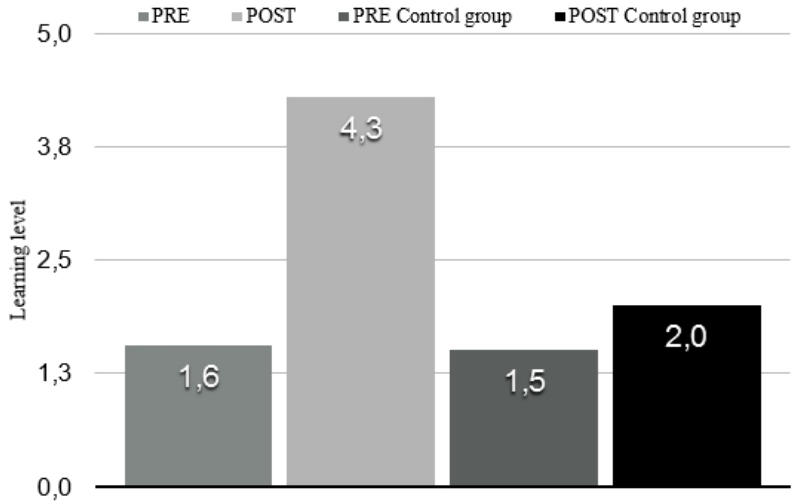


Figure 10. Difference between average values measured in pre-tests and post-tests, compared with control sample's results.

In Figure 10, the average of results is compared with control sample; in Figure 11 the CLIL approach data relative are compared with those of the mother tongue experimentation. We can notice no substantial difference exists between learning experience carried out in one's mother tongue and one carried out in a foreign language (CLIL approach).

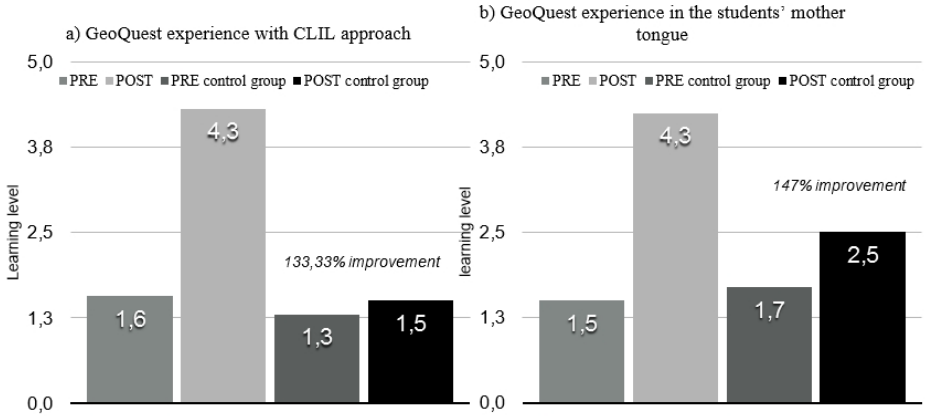


Figure 11. Difference between average values measured in pre-tests and post-tests for GeoQuest experience with CLIL approach (a) and with mother tongue (b).

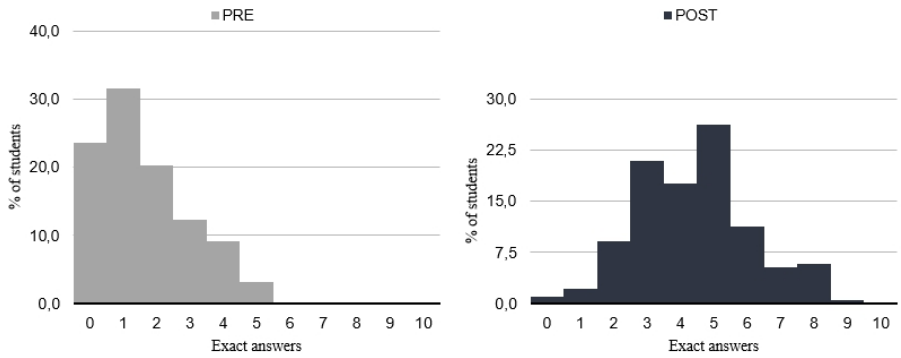


Figure 12. Percentage of relative frequency of correct answers provided in the pre-tests and post-tests.

Figure 12 shows the relative frequency percentage of correct answers provided in pre-tests and post-tests. The relative frequency percentage histogram of answers given to the pre-tests, shows (Table No. 11) that, on average, students answered correctly once every 10 times (media = 1,6). Students majority provided only one correct answer or none at all (median = 1); the number of correct answers provided by majority of students is 1 (mode = 1). The relative frequency percentage histogram of answers given to the post-tests shows that students answered 4,4 correct answers out of 10 on average (media = 4,4). Students majority provided up to 4 answers (median = 4); 5 (mode = 5) is the correct answers number.

Iceland-Italy teachers exchange

One of the authors won a teachers exchange (2017) funded by Science on Stage Europe. It aimed at the development of a Joint Project

between two European countries (Iceland and Italy): the chosen project was GeoQuest, so that a class from an Icelandic high school experimented with the Vesuvius path of CCRPG. In Figure 13 learning outcomes are shown, before and after the CCRPG. We chose to consider the mineralogy questions data (Figures 13 A, B, C, D) as they are among the "hardest" topics for students. Figures 13 E and F refer to same question: In one case (Fig. 13 E), question included four choices, which were the names of four different volcanoes. In the second case (Fig. 13 F), in the four choices were the volcanoes images, without their corresponding names.

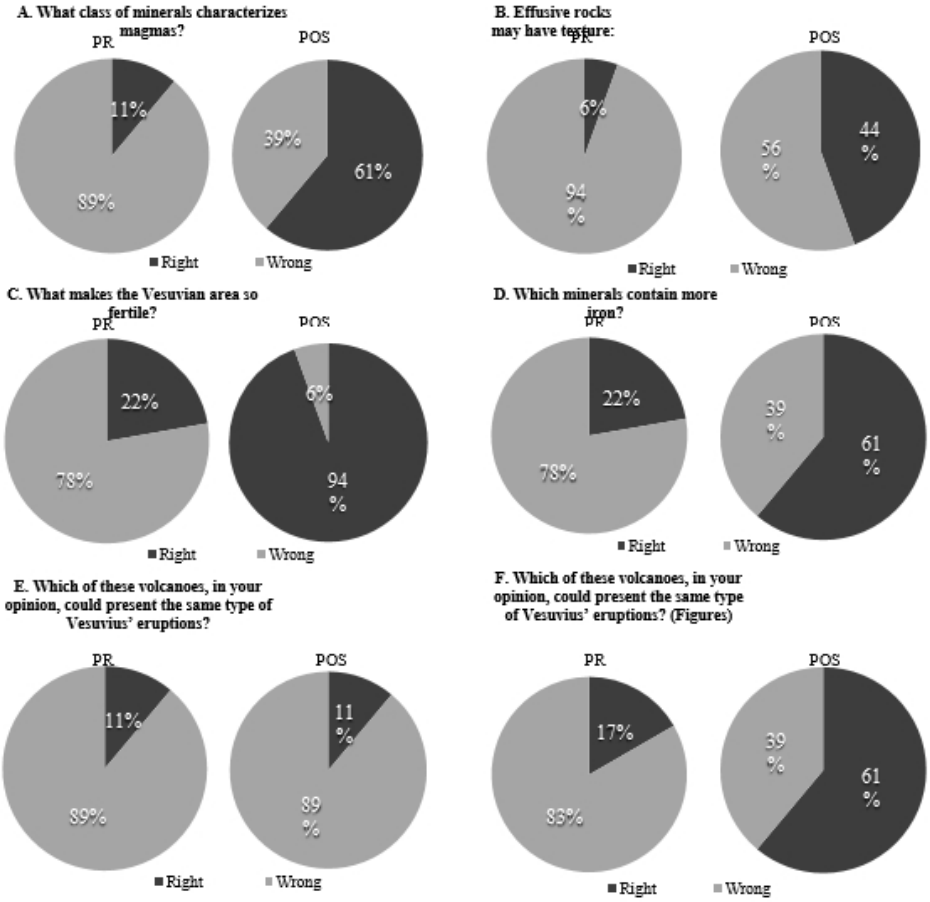


Figure 13. Pie charts for learning outcomes of Icelandic students, respectively before and after CCRPG. In red the wrong answers, in green the right answers.

Customer satisfaction

Table 12. Media, median and mode values for students' satisfactions.

Students Satisfaction	GeoQuest finding	Immersive environment	Smartphone use
Media	8,2	8,2	9,1
Median	8	8	10
Mode	8	7	10

Figure 14 points out: - the students' satisfaction, regarding overall experience

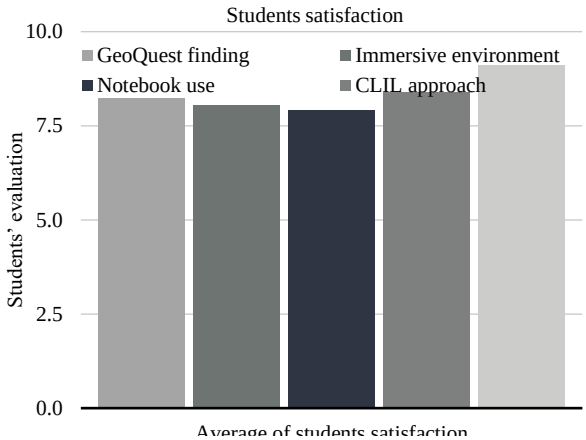


Figure 14. Students satisfaction.

with GeoQuest, - the learning environment, - the use of aids (notebooks), - the CLIL approach and the smartphones use. In this case, students were asked to express an evaluation from 1 to 10. The evaluations are fully positive (> 6). A more detailed analysis (Table No. 12) shows the overall experience with the CCRPG GeoQuest is evaluated by students with average rating of 8,2 (media = 8,2); students majority provided a 8 (mode = 8) value. The immersive environment is judged effective by all students (media = 8; mode = 7); more than half of students evaluate smartphones use with a value higher than 9, majority giving a 10 rating (Figure 15).

Table 13. Media, median and mode values for students of L'Orientale University.				
Students of L'Orientale University	**GeoQuest finding**	**CLIL compliance**	**Smartphone use**	**Interdisciplinary**
Media	8,7	9,4	9,6	9,2
Median	9	9	10	10
Mode	9	10	10	10

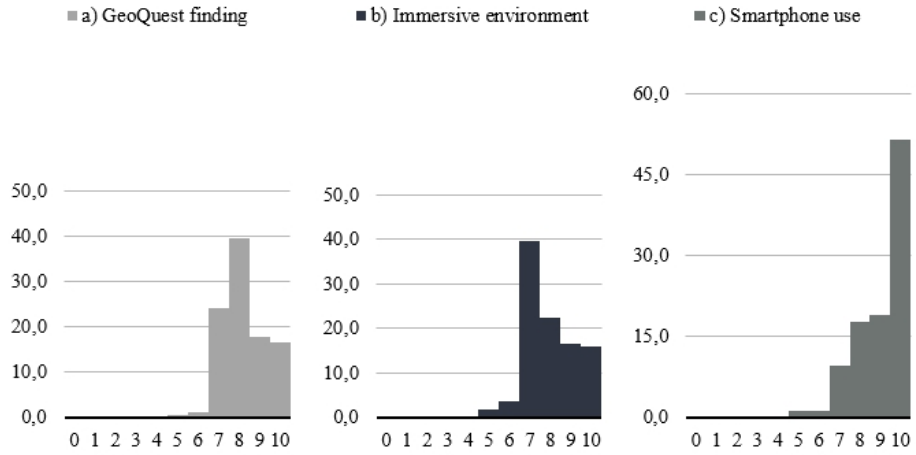


Figure 15. Percentage of relative frequency for students satisfaction.

The experimentation carried out with the "L' Orientale" University class group aimed at having a technical evaluation of experience with the CCRPG. In fact, university students had an Applied Linguistics training background in the Education Degree Course.

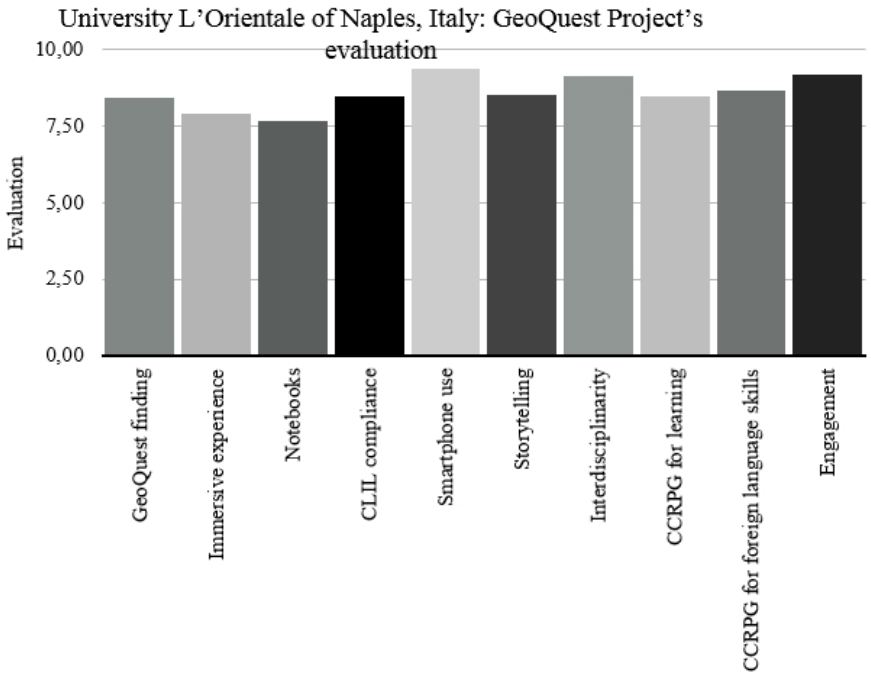


Figure 16. Students satisfaction measured in Education degree course by L'Orientale University of Naples, Italy.

In Figure 16 we can see evaluation average by "L' Orientale" University's students: all values are higher than 8,5. For a more detailed analysis we put together the evaluations concerning the same topic, and we calculated the relative frequency percentage of evaluations. Table No. 13 summarise media, median and mode values from evaluation by "L'Orientale" University undergraduates, while in Figure 17 we represented relative frequency of values in percentage. The technical opinion of the Education university course's students is very flattering: GeoQuest gets an average appreciation of 8,7 (media = 8,7); more than half of the students expressed an appreciation higher than 9 (median = 9). They considered brilliant the interdisciplinarity between scientific and humanistic topics, as well as the smartphone use to interact with the CCRPG (median = 10 and mode = 10). The most satisfying result is the evaluation of CCRPG GeoQuest for CLIL compliance (median = 10; mode = 10), being the university course specific for Education and applied linguistics.

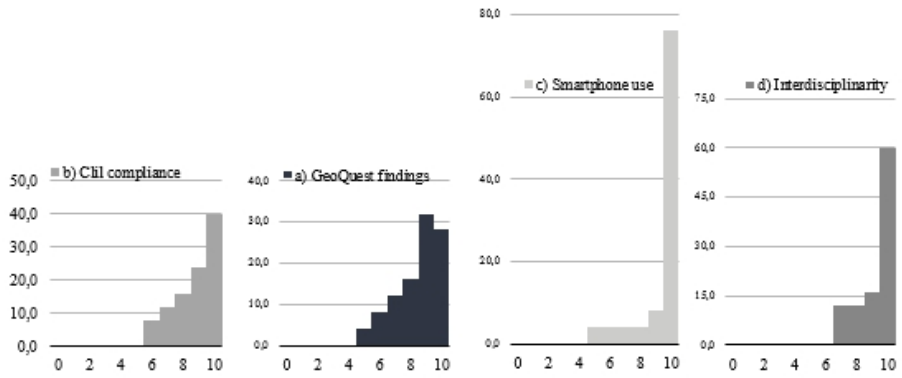


Figure 17. Percentage of relative frequency for students satisfaction, measured in Education degree course by L'Orientale University of Naples, Italy.

Teachers' satisfaction

Teachers were asked to rate some features of GeoQuest as well, on a scale of 1 to 10 (Figure 18). All ratings are very high; watching relative frequency (Figure 19), we can see that GeoQuest teaching experience got an evaluation higher than 9: more than half of evaluations are 10 (median = 10 in Table No. 14). The same opinion was expressed about interdisciplinary approach, laboratory teaching with the CCRPG and CLIL compliance.

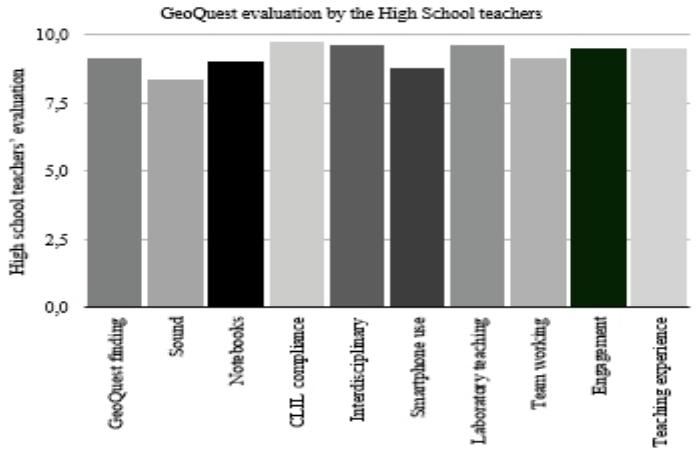


Figure 18. GeoQuest evaluation by the High School teachers.

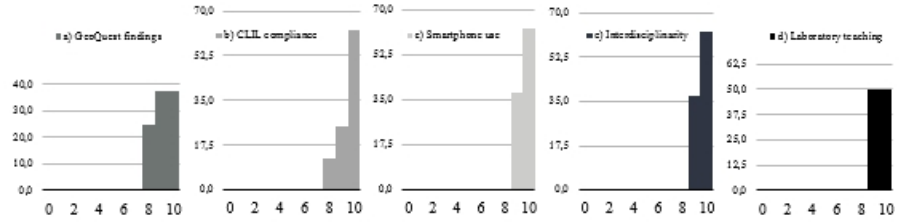


Figure 19. Percentage of relative frequency for students satisfaction, measured in Education degree course by L'orientale University of Naples, Italy.

Table 14. Media, median and mode values for high school teachers satisfactions.					
High school teachers	**GeoQuest finding**	**CLIL compliance**	**Smartphone use**	**Laboratory teaching**	**Interdisciplinary**
Media	9,1	9,8	8,8	9,6	9,6
Median	10	10	10	10	10
Mode	9,5	10	10	9,5	10

Furthermore, teachers of survey No. 2 (see teachers' needs in Table No. 2) had a learning experience with GeoQuest, as a tester of the innovative teaching tool, and evaluations about it, are summarised in Figure 20. Results are brilliant: see Table No. 15 and Figure 21.

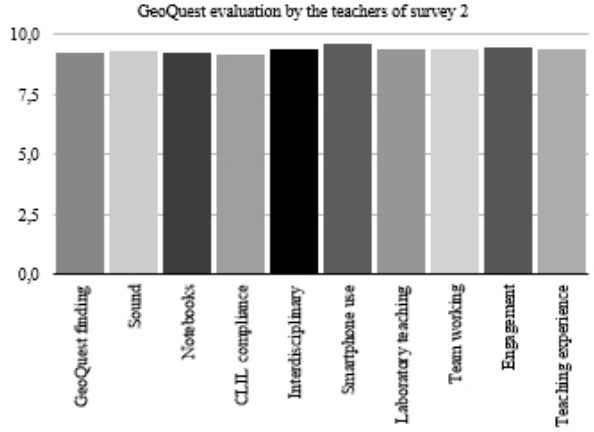


Figure 20. Percentage of relative frequency for students satisfaction, measured in Education degree course by L'orientale University of Naples, Italy.

Table 15. Media, median and mode values for teachers survey 2 satisfactions.					
Teachers survey 2	**GeoQuest finding**	**Team working**	**Smartphone use**	**Laboratory teaching**	**Interdisciplinary**
Media	9,2	9,4	9,6	9,4	9,4
Median	10	10	10	10	10
Mode	10	10	10	10	10

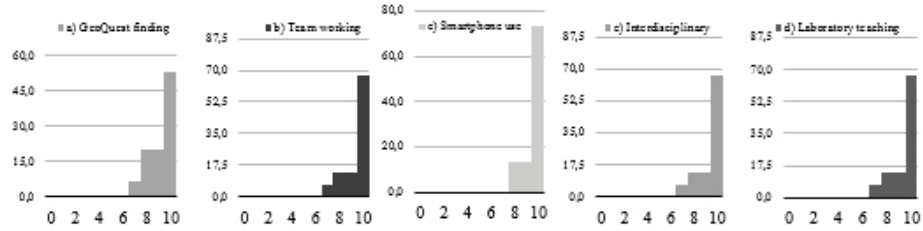


Figure 21. Percentage of relative frequency for students satisfaction, measured in Education degree course by L'Orientale University of Naples, Italy.

Discussion

We stated the experimentation of the GeoQuest project was divided into several phases, with the calibrating aim of project and then analysing its effectiveness in every school order. Satisfactory learning outcomes with the CCRPG in primary (up to 10-year-old students) and secondary (11-14-year-old students) schools have been illustrated in previously published works (Maraffi & Sacerdoti, 2016 b; Maraffi & Paris, 2017; Maraffi, Paris & Sacerdoti, 2017). Results obtained in technical high schools, where Science is only studied during the first two years, were also analysed (see References). We have concentrated the final phase of quantitative data analysis on high schools' students because their curricula contemplate the Earth Sciences study for five years. We have emphasised before, in the most recent analysis, Earth Science data, as the GeoQuest Project was developed as a doctoral project in Earth Science Education.

Results analysis referring to single classes (Fig. 9) shows that students' knowledge possessed before experimenting with the CCRPG, was extremely poor, if not null (Fig. 9c). We must bear in mind that these are classes for which topics covered in the CCRPG are part of curriculum program. Furthermore, six out of the nine classes examined are senior classes, for which game's topics are compulsory for the final exam (Figures. 9c, d, e, f, h, i, l). We can have a more detailed general idea if we analyze

percentages of the relative frequencies of correct answers (figure 12). In Figure 12a the values of mean, of median and mode are very close to each other: students' knowledge and skills in Earth Sciences, as they emerge from the pre-tests, are extremely disappointing, despite reforms, environmental issues awareness or the prospect of the final exam. Figure 12a histogram has a positive skewness: values distribution is shifted downwards. Although there are students more or less predisposed to study in the individual class groups, or differently interested, little or nothing is done in the field of Earth Sciences. The Figures 12b histogram presents a mode of 5, i.e. in the post-tests following the CCRPG there is a 400% improvement. Results are poorly dispersed (media = 4.4; median = 4; mode = 5); distribution is quite symmetrical, with a tail of higher results, compared to the lower ones (slight negative skewness). As already mentioned, such satisfying results can not be due to chance (Student test value). The excellent learning result obtained with the CCRPG GeoQuest is even more evident from comparison with control sample (figure 10). The CCRPG sample and the control sample started at the same level: improvement in learning levels measured after the CCRPG is 268.75%, while control sample after traditional lesson checks an improvement of 133.33%. Since traditional lesson followed by control sample had the help of multimedia and PowerPoint tools, we can conclude that it is not the multimedia tool itself to give a more profitable learning environment, but the CCRPG engaging and interactivity.

CLIL approach

The learning improvement get with CCRPG GeoQuest is the same (more than 268%), both with CLIL approach (Figure 11a) and with mother tongue CCRPG (Figure 11b). Control sample outcomes remain lower, but those of the CLIL approach are worse (133% improvement, Fig. 11a) than those obtained with the mother tongue (147% improvement, Fig. 11b). Therefore the CLIL approach reduces disciplinary learning results, if conveyed by lessons supported by multimedia tools; instead with the CCRPG you can obtain a foreign language learning (fluent understanding) without decreasing the contents and competences, proper of various subjects, learning.

Iceland-Italy teachers exchange

The Figure 13 shows that even the most difficult topics can be successfully learned through the CCRPG. A separate consideration must be done for Figure 13 E and F. In GeoQuest pathways no information is provided to answer these questions. Yet in the post-test of Fig. 13 F there is an improvement in the responses of 286.7%. Why? Because in the first case, answers made up only of names requires knowledge of names themselves: if

answers are not provided, they can not be invented. Instead, in the second case images require concepts that, although not provided, can be recovered thanks to skills acquired with the CCRPG activity.

Students and teachers satisfaction

While not being able to reproduce frequency charts for each of the proposed questions, for reasons of space as it would weigh down this paper, we chose to show frequency charts for topics considered most important. The evaluations requested to the students have all had excellent results. The Notebook use and the CLIL approach are teaching matters more than learning matters; therefore, we focused students' satisfaction on learning experience with the CCRPG. It should be noted that student judgments are not dispersed, but homogeneously concentrated in an excellence area. Naturally, technological tools use constitutes an engagement for students and in fact appreciation is highest (median = 10; mode = 10).

To the university students of Linguistics in Education a more technical evaluation, typical of their specific research studies, was requested, based on ten questions, as shown in figure 16. All evaluations are highly positive, so we have chosen to develop the relative frequency charts for 4 topics, which are the same on which evaluations analysis by other groups has been focused. Brilliant results here again, concentrated in an excellence area (figure 17).

Finally we summarise teachers results. High school teachers (Figures 18 and 19) have experimented the CCRPG GeoQuest with their students, the teachers of survey No. 2 (Figures 20 and 21) have personally experienced the CCRPG, evaluating its teaching and learning characteristics. The analysis of the data (Tables. 14 and 15) shows that teachers give an excellent evaluation to the teaching experience with GeoQuest and to the interdisciplinary approach, to the CLIL compliance, to the team working and laboratory teaching with CCRPG, to the use of ICT.

Conclusion

The final outcome is that GeoQuest Project effectively matches the needs identified by students and teachers. Carrying out the experimentation in several phases allowed us to calibrate and improve our product, GeoQuest project, in itinere and allowed us to obtain rigorous and certainly reliable results. This allows us to assert that we have been able to meet students and teachers' needs, with a teaching tool that perfectly complies with modern society demands. Above all, the project answers our research questions in teaching and learning processes in Science Education: "to create an educational tool that ensures students build knowledge of the disciplines founding cores in an interdisciplinary key". This goal allows students

acquire: - technical and technological skills, - mastery of foreign languages, - flexibility, - creativity and entrepreneurship.

At the same time our teaching tool, the CCRPG GeoQuest, favours teachers' teamwork and students' cooperative learning, allows teachers to apply the innovative teaching approaches needed today, in a user-friendly and satisfying way. The most important feature for us is that GeoQuest takes the Teaching and Learning Processes in Science Education (but not only) into account, at the same time. Until today, teaching products appreciated by the students were judged by the teachers either ineffective or too challenging. Teaching products pleasing to teachers, on the other hand, proved either ineffective for students or too obsolete. The Computer Classroom Role Playing Game GeoQuest, instead, ensures much higher learning outcomes than those obtained with other teaching tools, favouring scientific, interdisciplinary and digital skills acquisition (easy to evaluate, as well). It also meets students liking of both the game and the use of modern technology. On the other hand, teachers can use our CCRPG in an easy and quick way, they do not have to undergo specific training to manage it. GeoQuest allows: - a laboratory teaching, - the CLIL approach, - an application of the Inquiry methodology, - students engagement and authentic skills assessment. We consider it important to point out that experimentation results show that the CCRPG brings a significantly higher focus, with a persistent attention during whole game. We can conclude that it is not multimedia tool itself to give a more profitable learning environment, but the CCRPG engaging and interactivity.

Since the beginning of first experimentation step and as a result of the disclosure of our work, the requests to try the game have multiplied. The five already existing pathways will soon be joined by others already requested. Some schools, in different Italian regions, have placed GeoQuest at base of school projects to support learning or development of scientific and digital skills (Projects with Ministry of Education funds). GeoQuest was chosen to teach Science as a Joint Project between European countries by the executive board of Science on Stage Europe, which deals with the spread and sharing of innovative methodologies. They funded the exchange between Italy and Iceland for CCRPG methodology diffusion. A further exchange between Italy and Greece is foreseen and a moment of final sharing and results presentation is coming soon.

Another very important result is that in these projects the CCRPG tool sharing allowed other teachers to implement new adventure paths, working together with their students, both in Italy and abroad. This is really interesting because the creation of new adventure pathways activates useful skills in students (as digital and technological skills). Furthermore the practice of storytelling improves students' learning and search for various

building blocks game stimulates different channels of communication and learning (images, videos, audio, etc).

Finally, the positive experience with GeoQuest Project attracted a series of further related projects. We have already developed some education Apps to correct behaviour during emergencies, diversified by age and subject (seismic emergencies and volcanic emergencies in particular), and others App have already been requested. We have also been requested to apply the CCRPG to tourism: with adventure pathways creation that allow the Italian and foreign natural and artistic heritage fruition.

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