NEW METHODOLOGIES AND TECHNOLOGIES IN EARTH SCIENCES EDUCATION: OPPORTUNITIES AND CRITICISMS FOR FUTURE TEACHERS

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ABSTRACT

During the academic year 2017-2018, the *Università degli Studi di Milano* organized an educational path (*For24*) useful to acquire or to complete the personal training in educational disciplines and in methodologies and technologies for education, nowadays necessary for the teaching profession. The course in Earth Science Education has been attended by about two hundred trainees. The scheduled program complies with the indications presented in the Ministerial note (2017 August) and it focuses on: epistemological and methodological-procedural bases and on approaches in Earth Sciences education; Earth Sciences education in laboratory and in the field; methodologies and technologies to study relationship between Earth Sciences and the present Society (geo-resource sustainability, natural risk prevention, cultural and geological heritage); teaching and learning procedures based on the use of the new technologies and multimedia tools. In this paper, we analyze the population of trainees who attended the course, the results of the final exams and we discuss criticisms related to the Geosciences key concepts.

RIASSUNTO

Durante l'anno accademico 2017-2018, l'*Università degli Studi di Milano* ha organizzato un corso di didattica (*For24*) utile per acquisire o completare la preparazione personale nelle discipline dell'educazione e nelle metodologie e tecnologie didattiche, competenze attualmente necessarie per accedere alla professione di insegnante. Tra i vari insegnamenti è stato proposto un corso in didattica delle Scienze della Terra. Il programma ha seguito le indicazioni della nota ministeriale (agosto 2017) e si è focalizzato sugli aspetti epistemologico-procedurali e didattici delle Scienze della Terra, sulla didattica in laboratorio e in campo, sulle metodologie e tecnologie per lo studio dei rapporti tra Scienze della Terra e Società attuale (georisorse, georischi, patrimonio geologico e geomorfologico) e sulle tecniche di insegnamento basate su nuove tecnologie e strumenti multimediali. Nel presente lavoro vengono analizzati il campione dei partecipanti al corso, i risultati degli esami finali e vengono discussi gli aspetti critici dei nuclei fondanti delle Scienze della Terra.

Key words: Earth Sciences education, Geoeducation methodologies, Geoheritage, Georisk.

Parole chiave: Didattica delle Scienze della Terra, Metodologie didattiche per le geoscienze, Patrimonio geologico, Georischi.

INTRODUCTION

The teacher recruitment in Italy has changed after 2015 with a new law in 2017 (D.Leg. n. 59/2017) but it could be under revision with the new government. Graduated students can now participate to the competitive exams to become teachers not only if they have acquired specific degrees, as in the past, but also if they have undergone academic exams in the frame of disciplines as anthropology, psychology, pedagogy and methodologies and technologies for education (acquisition of 24 credits, D. M. 616/2017) and if they have acquired a minimum of academic credits, in specific scientific disciplines among which Earth Sciences (attached to D. M. 259/2017). During the academic year 2017-2018, the *Università degli Studi di Milano* (UniMi) organized an educational path (named

For24) useful to acquire or to complete the personal training in educational disciplines and in methodologies and technologies for education.

About 4,200 students have been registered in the *For24* path. Among these, a little more than two hundred trainees decided to attend the course in *Earth Sciences education* (ESe). The course program complies with the indications presented in the Ministerial note, published in 2017 August. Similar courses have been organized in different Italian universities, following the same contents as proposed by researchers from Torino University.

The ESe course focuses on: i) epistemological and methodological-procedural bases in Earth Science education; ii) methodological and technological approaches; iii) Earth Science education in laboratory and in the field: iv) methods; didactical methodologies and technologies to study relationship between Earth Sciences and the present society (environmental education; geo-resource sustainability, natural risk prevention, cultural and geological heritage); v) teaching and learning procedures through the use of the new technologies; vi) efficacy of multimedia instrument in Earth Science education.

Each University has aknowledged these key concepts with different strategies, scheduling specific educational geological contents. Professors and researchers from Earth Science Department of UniMI approached each scheduled point presenting tested projects, educational experiences in the field and in laboratory/museum as well as methodological approaches and paying attention to the new technologies useful in Earth Sciences education.

More in detail the first part was strictly focused on the general educational topics with a pedagogical approach; for what concerns laboratory and field experiences (Pelfini et al., 2016) our scheduled Earth Sciences topics focused on specific projects as *Big History* (Porta et al., 2018a) and Geosciences Theatre (Porta & Paris, 2018b), on field observation and field work as for Geomorphology (*Gekologia* project, Bollati et al., 2016; 2018b) and *A fly in the time* project, Bollati et al., 2011), laboratory activities as for minerals and rocks (e.g. Scacchetti & Bertacchini, 2018), Paleontology, Geoarchaeology and Geopedology and finally examples and projects for what concerns the relationship between Geosciences and Society as seismic, volcanic, hydrological and glacial risks, geo-valorization (Magagna et al., 2013) and geo-conservation, all of them for education.

The attitude of trainees and future teachers involved in teaching Earth Sciences together with a specific background, represents a key point for improving the quality of teaching and to get in students a better awareness of the processes acting on the Earth and their own territory (see among others Sturani, 2016; Sturani et al., 2018).

The aims of this paper are to analyze: i) the population of trainees who attended to the Earth Science education course, ii) the results of the final exams and iii) to discuss criticisms related to the Geosciences key concepts.

MATERIALS AND METHODS

Education approaches in Earth Sciences represent an important tool among the scientific goals of academic researchers (e.g. Pelfini et al., 2018b). Lessons have been organized in order to present methodological approaches to teach the several topics of Earth Sciences. When it was possible, specific methodologies were proposed in relation with the student target (e.g. how to approach the same argument in different types of school and in different scholar years). Video and results from previous educational projects have been proposed as well as an assessment questionnaire. Lessons specifically concerned with didactics and educational approaches as requested for the specific program *For24* (Kanizsa, 2004). All the showed material was uploaded in a specific site dedicated to participants. Each of the exams (four sessions) consisted in a test (18 questions, Q1-Q18, multiple choices) strictly referring to the lessons content and to the uploaded material (tab. 1). Questions followed the scheduled program. Each question regarding Earth Sciences was formulated starting from images, described situations, hypothetic visit in a museum or laboratory etc., and candidates were asked to recognize the right/wrong answer supposed to be chosen by their students. Generally questions for the same "Q" concern the same general topic but regard different arguments or require different answers. For example Q1 concerns geomorphology in all the four sessions but questions are based on different images and situations (e.g. in S1 recognize the reason why a braided Apennine river changes its habitus in correspondence of a resistant rock outcrop, in S2 recognize the main geomorphological agents in a picture representing potholes, in S3 recognize among three proposed student answers the one demonstrating if the goal "recognize the river shape" was reached). A different example is represented by Q5: in each exam session, the figure is the same and represent the depth and magnitude Earthquakes distribution but questions are different, and from S1 to S4 they focus on teacher choices to propose specific arguments concerning the image.

Two categories of questions composed the text: i) 1 right answer, 1 partially right (not complete or containing one error), 1 wrong answer; ii) the right answers can be one or two. In the first test category (T1), the candidate could make only one choice, while in the second one (T2), the candidate could make one or two choice, but without knowing if the right answers were one or two (tab.1). The sampling questions Q1 and Q5 proposed above belong to T1. Representative of T2 category can be mentioned Q17 for which four different activities at a geo-museum are proposed for S1-S4 and it is asked to candidates for example what kind of rocks or mineral they need to check before starting a visit.

Evaluation was in thirties; from 30 up to 35 points the final mark was 30/30, while for 36 points the final mark was 30/30 cum laude.

An anonymous questionnaire addressed to analyze participant's characteristics was also distributed.

The method used for data analysis is that of cluster analysis. In this way, it was possible both to maintain the anonymity of the questionnaire and to create homogeneous groups. Clustering can be formulated as a multi-objective optimization problem (Van Driel & Verloop, 1999).

Tab1. Questions typology for each exam session. Table presents the main topics concerning single questions. From Q1 to Q13 questions belong to T1, from Q14 to Q18 belong to T2. Generally questions for the same "Q" concern the same general topic but regard different arguments or require different answers.

RESULTS

The participants were people with a master degree, Ph.D students, post doctorate researchers and master degree students as the current normative allows to acquire the requested academic credits in anthro-psyco-pedagogical disciplines and in methodologies and technologies for education both during the academic courses or after their conclusion.

Overall, 198 people sustained the final ESe exam: the greater part of the participants attended the first session (97), while the following sessions were characterized by a progressively decreasing number of candidates (i.e. 50, 35, 16).

SAMPLE FEATURES

The sample is made up by about 60% women and 40% men; it is mainly constituted by second level graduates (90%). The second level graduate students (fig.1a) have mainly a degree in biological field (47%), then in the geological-naturalistic-environmental area of interest (29%). The engineers and architects are only 9%; the graduates with Agriculture and Forestry Sciences degree are 8% and the graduates in Math and Physics are about 5%.

Fig 1 Sample features - 1a: field degree; 1b: previous teaching experience; 1c: where participants want to teach.

As far as it concerns their previous experience as teachers (see Goldhaber et al., 2013) (fig.1b) in the secondary school (I and II levels), about 56% of the sample has not yet experienced teaching or, it was not for a significant period (less than 1 year). Nobody declared a previous teaching experience greater than 6 years and only 3% has an experience in the range of 4-6 years. The remaining 41% declares to have a teaching experience for 1-3 years.

The previous teaching experience, if present, have been mainly acquired in the first level secondary school (54%); the others have worked in the second level secondary school and, in detail, in high schools (lyceum) (22%), technical institutes (23%), professional schools (12%). Shares do not add up to 100% because some of them have worked in different schools.

The First-best career choice (fig 1c) is mainly to teach in high schools (lyceum) (121 preferences vs 198). 72 of them do not want to teach elsewhere. 72 trainees prefer the first level secondary school and 51 of them want to teach only in this kind of school (or they can teach only in this kind of school, in relation with their degree). The remaining ones are oriented towards technical and professional institutes.

It is interesting to note that about 21% of the interviewed participants is indifferent to the kind of school, even if they generally express a preference for high school. We have to remember that the trainees could mark more than one choice.

ASSESSMENT QUESTIONNAIRE

The questionnaire, proposed during the last lesson, was filled out by 30 participants (21 teachers (70%), 1 graduated and 1 researcher (6%), 3 PhD students (10%) and 4 students (14%). Among the teachers, 63% of participants had never sustained an academic exam in Earth Sciences, 10 % 1-3 exams, 27% more than 3 exams. All of them believed that this course was useful to learn how to teach. Very interesting are the open answers. As far as concerns the mentioned positive aspects, there are some useful hints for teaching, the attention paid towards new methodologies and technologies, multidisciplinarity and links to everyday life, experimental educational projects. Suggestions state the need to directly experimenting laboratory activity and working in team.

EXAM EVALUATION

The mean evaluation, expressed in thirtieths, is very high (29.5/30). The score obtained by students non-yet graduated is 28.5/30 (with a modal value of 30.00, but with a relevant standard deviation). The score obtained by the graduates is 29.6/30 (with a modal value of 30.00 and an even more relevant standard deviation). Therefore, there is not a substantial difference between these two groups of students.

It is interesting to observe the score trend (fig. 2a): the highest grade decreases from the first to the last exam session, nevertheless nobody obtained 30/30 cum laude. As regards of the evaluation class 30/30, in the first two exam sessions, scores higher than 30 range from 43% to 55% while in the third and fourth session they range from about 8% up to 12%, while the score 30 is quite similar in all the four exam-sessions. On the contrary, the evaluation classes 29/30 to 30/30 are more fluctuating, and the evaluation class 24/30-26/30 is more present in the last two exam sessions, while the lower evaluation classes (23/30 - 18/30) are represented by very few units and they are more present in the third session.

The performance is positively related to the previous teaching experience (fig 2b). Candidates without previous teaching experiences, or with low experiences, obtained on average lower test scores than the others.

The degree background (fig.1a) is also compelling as far as it concerns the final evaluation results (fig 2c): the best results, 30 and higher scores, have been reached by participants graduated in geological-naturalistic-environmental science fields, while lower results (anyway high) correspond to graduates in other titles: agriculture and forestry and math and physics.

Fig 2 Exam evaluation - 2a: exam results; 2b: relation with the previous teaching experience; 2c: relation with the degree background

TOPICS, THEMATIC RESULTS AND CRITICISM

In the present section, results related to thematic questions are analyzed. Questions (tab.1) have been proposed only through their educational approach. No questions on specific knowledge (contents) have been inserted in the test but only educational approaches. Nevertheless, base concepts in Earth Science were implicit. Questions were often based on images, specific contest (laboratory, field, museum).

In the first questions test category (T1) candidates whose answer were evaluated 2 points, obtained an average of 79 points (88 in S1, 84 in S2, 69 in S3, 75 in S4, where S means session) while in the second test category (T2) candidates obtained a significant lower average overall value (39) (respectively points 46, 47, 34, 30 in the four successive exam sessions). If we consider completely wrong answer, similar results were obtained for answers belonging to T1 and T2.

Earth sciences education in laboratory and in the field

The first question (Q1, T1, tab.1) in each session was about geomorphological processes approached through fieldwork and field trips. Topics concern morphological and fluvial processes, river characteristics and lithological control, glacial modeling under different geological conditions, landscape and landforms characteristics and changes under changing climatic conditions. Higher scores are related to river and fluvial processes but the question concerning more detail on the same topic (riverbed shape) (Q1 S3 - 3rd session) appear to have been more difficult for candidates.

Q4 and Q5 (T1, tab.1) were focused on the use of different approaches to teach fundamental geological subjects, as plate tectonics, but starting from the observation of data and the analysis of them. Candidates were invited to select themes that would be possible to approach starting from images showing distribution of geological data. Since during the lessons and laboratories the advantage of using real data observation making use of new technologies such GIS-based software (e.g. GeoMapApp software at www.geomapapp.org) was stressed, Q4 was focused to check if the candidates were confident with main plate tectonics related subjects as seismology, volcanology, paleomagnetism. The results were quite good, showing that most of the candidates are able to deal with such subjects, even though not with a standard approach. Q5 started from real data, earthquakes distributed along the Pacific Coast of Central America. Here candidates were much less able to approach differently the topic and most of them selected a more conservative answer, at least during two of the 4 tests, and the percentage of failure has increased during time.

Laboratory teaching of minerals and rocks was approached by stimulating the importance of making students aware, at any level, of the diffusion and distribution of natural minerals or rocks in their present-day life. Minerals and rocks (Q7, Q8; tab.1) were presented not only as ornaments but also as pieces of natural history and as a source of elements essential to make objects of common use, like mobile phones. To further stimulate students, a particular effort was used to demonstrate also how traditional *static* exhibition of samples, like minerals and rocks in a museum, could be used for a *dynamic* learning (Q 17). Teaching examples through time and space were proposed. Q7 and Q8 obtained good answers while Q17 (T2) generally obtained partially right responses.

Q9 and Q11 (T1, Tab.1) were respectively related to Geopedology and Geoarchaeology, in order to stimulate interdisciplinary connections between Earth Sciences and Life sciences (i.e. soil system) or humanities (i.e. geological methods applied to Archaeology). In both cases, results are encouraging: about Q9, the percentage of correct answers ranges from 71% to 94%, while about Q11, from 69% to 88%.

Earth Sciences and Society: geo-resources

The approach to the geo-resources was based on their high impact on everyday life, with examples starting from objects used daily and going back to the geomaterials used for their production, mineral transformation from mines to everyday tools. Geomaterials can also be considered for their link with local territory, planning educational fieldtrip also in geotouristic mining sites. The question concerning georesources (Q16, T2) was aimed to outline the importance of their link with daily experience and local territory. Results show that less than half of the questions were fully right answered and only 5.1% were fully wrong. Higher scores were obtained for questions concerning daily experience than for those concerning local territory.

Q17 was also planned to outline the possibility to use minerals and rocks for telling geological and technological history. On average, only 5% of candidates gave a completely wrong answer and the percentage of fully wrong answer increases from first two exam sessions to last two sessions.

Earth Sciences and Society: methodological and technological approaches for geo-risk education

Georisk education was approached in relation with both endogenous and exogenous processes. Questions on geomorphological hazard/risk were mainly based on photos where the candidate was asked to recognize geomorphic evidences of hazardous events. The same approaches were used during lessons to outline the importance of observation, a concept underlined by ministerial note for the first two years of the high schools. Q15 (T2) obtained the lower results. Even if 0 point have been obtained only in the 5% of cases, the 20% is concentrated in the 3rd session where to identify avalanche risk it was important not only consider geomorphological evidences but also vegetation features.

Volcanic and seismic hazards questions concerned the use of maps and images to infer useful information on these risks. Results are below the average with 2 points at 34.3% only and 0 points at 20.9%.

Earth Sciences and the present Society: Cultural heritage

Geoheritage, being part of the Natural heritage, is again part of the Cultural heritage (Panizza & Piacente, 1993). The scientific attribute, that represents the “core” of geosites evaluation (Reynard et al., 2007), can represent also a starting point for unconventional teaching in Earth Sciences. Educational values, strictly linked with Potential of use and Accessibility are key elements in organizing educational activities in the field (Bollati et al., 2014, 2016). Q10 in all the four exam sessions focuses on geoheritage and education and aims to investigate candidate’s affinity with this topic, that was discussed during lessons. Basic concepts concerning models of geomorphological evolution in relation with climate change were proposed in different ways. Best results (88%) regard basic concepts while the identification of specific values represented a higher difficult for candidates, even if discussed. Nevertheless, wrong responses range from 0 to 11%.

Methodologies and new technologies, epistemological concepts in Earth Sciences education

As far as the methodological-didactic nature is concerned, theoretical questions were formulated, for example on the teaching method of the discipline, and practical questions concerning the methods of Earth Sciences teaching in the classroom, also with reference to the use of multimedia tools were proposed too. In general, the theoretical questions were accepted as more difficult while the practical ones obtained more correct answers. This is further confirmed by the results of the fourth exam session in which no theoretical questions were inserted: in this case, the results are undoubtedly better.

DISCUSSION

The analysis of the sample features and of the exam results allow formulating some interesting considerations.

With respect to the past, people who attended the recruiting program named *For24*, even if graduated, have not taught as precarious teachers for a long time. As usual, they are mostly women, but with a lower weight than in the past. This could mean a renewed male interest in teaching, but also, on the other hand, could show the effect of the economic crisis on the labor market (Treu, 2013). This could mean also a starting change respect to the recent past: previous studies have revealed that the majority of Science teachers, anyway enrolled not very young, were graduates in biological sciences and there were very few science teachers with another degree. (Sturani, 2016; Realdon et al., 2016).

Most of the trainees are particularly interested, if they have the law requirements, in teaching in high schools. It could probably depend on the higher wages paid for teaching in high schools, on the subjects they could teach and on their importance in the different types of school.

Exam results are generally high positive and there is a positive and stable statistical correlation between trainees' previous teaching experience and their exam performances. Nevertheless, globally results in T1 are better than the ones in T2: in the second category of questions, candidates preferred to give two answers, increasing the probability of taking 1 point but decreasing that of taking 2. Fieldwork and fieldtrip (e.g. Garavaglia & Pelfini, 2011) were recognized as correlated to trainees' previous experience (Sturani et al., 2018). Nevertheless, positive exam results show a good attitude of the sample in new educational approaches.

Even if the course was frequented in presence only by about one third of the registered, participants really appreciated the focus on the educational approach of the Earth Sciences and on the use of real data, field data, images, online tools etc., for unconventional teaching. Anyway, the great variety of candidate's degree evidence a diffuse lack of geological contents in their own background. This is also demonstrated by the different suggestions expressed in the satisfactory questionnaires: people whose background is far from Geosciences hope for more geological contents in future courses (in contrast with the goals of the course itself, which complain with the ministerial indications) while people who have sustained geological exams in their academic courses hope for practical teaching experience (see Magagna et al., 2018 for didalab experience).

Even for what concerns Earth Sciences topics, some considerations can be done: results are generally good for educational base concepts, methodologies, and technologies (e.g. Porta et al., 2016) discussed during the course and supported by the uploaded materials. Quite different are the results concerning educational approaches to the different topics as contents, even if very simple and retrievable from school texts, needed to be known. For example, regarding Geomorphology and Physical Geography, if questions concerned topics more linked with arguments approached by candidates in their previous formation, since the high school, (e.g. fluvial modeling) the results are high while if new topic are proposed (as glaciers and glacial modelling in relation with climate and vegetation; Pelfini, 1999; Porta et al., 2018c; Pelfini et al., 2014) or if a different reasoning is requested (observation, the main aim for the biennium in high school) the answers are often wrong. The use of real data to comprehend plate tectonics obtained very good results and demonstrated how experimentation allow to better comprehend a key concept of Geosciences. For Geo-resources, mineral and rocks, we notice that the essential knowledge of Earth materials is assessed, but the not negligible presence of negative scores on modern topics reveals that the details of geo-materials do not constitute an obvious background (Porta et al., 2018 d). Nevertheless, the proposed educational project (Bollati et al., 2013; 2014; 2016), organized (Pelfini et al.,2018a) and/or tested with different school classes (Bollati et al.,2018b) obtained a great interest in attendees as they demonstrated good results in experimenting students as well as a better ability to get awareness about geological processes and their implications in the everyday life, considering both resources, leisure and recreational activities (Bollati et al., 2018a) and risk.

For interdisciplinary connections between Earth Sciences and other sciences and/or humanities, the heterogeneous cultural backgrounds of candidates, could be a good starting point in order to better understand, and further teach, the existing links between usually disconnected disciplines in the

Italian secondary school system; however, an improved knowledge in the Earth Sciences, is a crucial point, also in this case.

CONCLUSIONS

In conclusion, we can state that for many years the Italian private job market has been more attractive than the public one because the wages were higher and precariousness lower. Now, jobs in the private sector are precarious too and wages are decreasing. School teaching jobs become a solution for graduates who would not have chosen this profession by their hearts. In this way, now it is the public job market which is more attractive. Nevertheless, results from ESe course evidence how specific courses which link methodology for education and Earth Sciences concepts appear useful and necessary for trainees, especially if they haven't never got in touch with geological topics in their previous formation.

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