

A Study on Science Teaching Efficacy Beliefs During Pre-Service Elementary Training

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Abstract

Two science teaching workshops for students of the elementary teacher education degree course at the University of Palermo, Italy are discussed, one based on inquiry-based methods and the other on "traditional" teaching methods. A questionnaire aimed to understand the teaching styles preferred by students, their reasons for learning/teaching science, and their beliefs about the difficulties a teacher faces when planning and trying out science teaching activities in the class were completed by the students before the first workshop, at its end, and the end of the second workshop. The answers given by the students were studied using cluster analysis methods. The results of the analysis of answers given to initial and intermediate questionnaires indicate that the students recognize the importance of teaching scientific subjects in elementary school. However, the self-perception of their abilities to effectively teach science is negative, both before and after attending the "traditional" type teaching workshop. After doing the inquiry-based teaching workshop and holding several days of a science fair, most of the students' negative beliefs have changed into positive ones. A better general understanding of the fundamental role played by the teacher in encouraging the natural curiosity of children and offering scientific activities based on everyday life experiences was observed.

Keywords:

Cluster Analysis, Elementary School Teacher Education, Science Teaching In Elementary School, Teacher Belief About Teaching

Introduction

In recent years, the results of many national and international research projects and scientific reports by the European Commission (e.g., Rocard et al., 2007) and other organizations (AAAS, 2002; NRC, 2012) have shown that the unsatisfactory results often attained by pupils learning scientific subjects in schools may partly be due to the way that these subjects are taught. "Traditional" science teaching is, in fact, often based on approaches only involving the transfer of pre-determined and already established content, with no reference to everyday life situations or previous knowledge that the students already



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possess. In this context, students take on a passive role in learning and rarely have the opportunity to follow the procedures that are typical of scientific methods. Such a way of teaching science may wrongly shape students' ideas and beliefs (Schoen & LaVenica, 2019; Irez, 2007) about science and its nature, by making them convinced that scientific knowledge is mainly based on a mere description of results presented as "true" and "precise" because obtained using "the Scientific Method" and that science subjects are "too difficult" to be taught at lower school levels, such as at elementary or middle school.

Unfortunately, this can be true also at the university level, even in degree courses aimed at pre-service teacher education. Besides coming to the courses with various levels of content understanding (e.g., Gupta & Lee, 2020), the trainee teachers are too often exposed to a teaching approach based on a lecture format and a few laboratory activities restricted to a mere verification of some physical laws. In some cases, they are also asked to seamlessly apply the theoretical concepts learned in Pedagogy courses to plan science teaching units, leaving them the endeavor to "didactically reconstruction" the science contents to be taught. It has been shown that teachers exposed to this kind of pre-service education often resort to the traditional practices of content-focused instruction in science, merely transferring to their students the perceived didactical methods and learned contents (Sperandeo-Mineo et al., 2006), without any effective adaptation to the specific teaching context. Moreover, this is often done by simplifying the approaches learned at University and basing them on transmissive teaching models found in textbooks (e.g., Sprinthall, Reiman, & Thies-Sprinthall, 1996).

The experience that these students had with studying science (both during their school years and pre-service teacher education) may lead them also to develop low levels of science teaching efficacy beliefs, and, in turn, guide how they plan for their future classroom activities and practices and shape teachers' behavior during classes (Samuel, 2017; Samuel & Ogunkola, 2015; Lumpe et al., 2012; Marshal et al., 2009; Calderhead, 1995; Pajares, 1992).

Many research studies (e.g., Siswono et al., 2019; Purnomo et al., 2017; Teng, 2016; Kirkgöz, 2016; Buczynski & Bobbi Hansen, 2010; McDermott & DeWater, 2000) have focused on the impact of teacher professional development programs on teacher belief systems (Di Martino & Sabena, 2011; Zan & Di Martino, 2020), teaching practices and student learning, and on the advantages of programs based on developing scientific investigation and discovery processes (inquiry-based science education, IBSE (e.g., Bybee, 1993)). Such processes are widely considered a way

of shaping future teachers' beliefs about science and improving understanding of the sciences and their working methods. Moreover, many researchers have trialed questionnaires designed to measure teachers' beliefs about teaching and learning during teaching practice. Most of the items ask teachers to report on their subject-neutral beliefs about teaching and learning, and some specifically ask teachers about their beliefs about teaching and learning (e.g., Clark et al., 2014; Peterson et al., 1989; Schoen, & LaVenica, 2019). Therefore, training programs for teachers, like the ones included in elementary teacher education degree courses, must be rethought to allow trainee teachers to get to grips with approaches to teaching planning like the inquiry-based (IB) one, which are specifically aimed at allowing students to construct scientific knowledge actively. With these approaches, the teaching methods studied during the theoretical courses on didactics and pedagogy of the degree course must be put in use in the specific context of science to encourage an authentic "educational reconstruction" of the scientific content to be taught (e.g., Duit et al., 2012). Furthermore, the trainee teachers must be explicitly invited to put their scientific knowledge to the test, and possibly improve it, by trying out the learning pathways themselves, and sharing, discussing, and bringing the activities they have planned into the classroom, and possibly to science fairs. This may encourage a careful reflection on pupils' learning difficulties based on the activation of reflection/metareflection processes (Karamarski, 2017; Simons, 1996; Schön, 1988) in the trainee teachers. The final aim is to trigger the construction of particular forms of knowledge, like the well-known "Pedagogical Content Knowledge" (Shulman 1986, 1987), which Zeidler in 2002 summarized as the ability of a teacher to convey the essential information in a way that is clear, engaging and accessible to students.

In recent years experimental educational researches focused on the effect on trainee teachers' epistemological beliefs and beliefs about the teaching of reforms of training programs have been discussed in the literature (e.g., Hsu, 2005). Many of them use descriptive statistics, analysis of the variance/covariance (Anova/Ancova), correlation analysis, etc., for analyzing the related data.

In this paper, we describe a research study performed with students from the fourth year of the elementary teacher education degree course (from now on, trainee teachers) at the University of Palermo, Italy during the academic year 2018-19. The research was focused on the effects of two physics teaching workshops on trainee teachers' beliefs about science teaching. One of the workshops was based on "traditional" methods, which are commonly used in teaching workshops on the degree course they are

attending, and the other was explicitly inquiry-based. Particularly, we discuss here the results of a quantitative analysis of the answers given by the trainee teachers to a questionnaire, inspired by other questionnaires used in Seventh Framework Program (FP7) projects financed by the EU and focused on IB education, and adapted for the specific context of the research. The analysis was done by using a novel methodology for educational research based on cluster analysis (CIA) (e.g., Everitt et al., 2011), that allowed us to classify the trainee teachers in different groups or clusters and build trainee teachers profiles without any prior knowledge of what forms those groups take (unsupervised classification, (Sathya & Abraham, 2013; Dayan, 1999)). The clusters were, therefore, analyzed to deduct their distinctive characteristics and to point out similarities and differences between them.

The questionnaire was given to trainee teachers to complete before, during, and after the two workshops. Its purpose was to get insights on possible effects the two different methods used in the workshops may have on the preferences expressed by the trainee teachers about how to teach science to children, on their ideas about the difficulties an elementary school teacher encounters when planning and carrying out science teaching activities in class, and more generally on the trainee teachers' motivation for learning and teaching science.

Inquiry-Based Teaching and The Need for Adequate Teacher Training

IBSE is today as one of the most popular topics in projects aimed to reform the way science subjects are taught at all schooling levels. Various FP7 and Horizon 2020 projects in the area of science and mathematics¹ have promoted the development of IB teaching methods and encouraged experimenting with their use, and continue to do so. These projects support the actual implementation of teaching practices based on a scientific investigation through the parallel development of scientific content and processes of active construction of knowledge by learners, using innovative teaching methods (Battaglia et al., 2019a; Battaglia et al., 2017; Pizzolato et al., 2014; Bolte et al., 2012).

On the other hand, educational research has shown that in many cases, the meaning of IBSE is not entirely clear even to teachers with proven experience, who, according to the National Guidelines, should be responsible for implementing methods based on a scientific investigation in their teaching practice (see National Guidelines of many countries and also NRC, 2012). For example, in some teacher resources a definition of IBSE can be found merely as: "the application of scientific methods to teaching". During

their university studies, many teachers learned that scientific investigation could be reduced to an almost "mechanical" application of a well-defined number of "steps" to be followed, which invariably lead to the description and explanation of an observed phenomenon.

The idea that science, and even worse, learning about science, can be reduced to a simple linear step-by-step procedure does not take into account other aspects that are typical of scientific investigation. The creativity of the researcher, which is fundamental in the process of constructing knowledge, and the centrality of sharing the results obtained with peers, are relevant. IBSE also sets ambitious objectives for the students, and this makes the role of the teacher even harder if that is possible (Marx et al., 1997; Roehrig and Luft, 2004). However, many teachers were trained in university courses based on traditional forms of teaching, which are merely aimed to transfer content about the subject being taught (Windschitl, 2003).

Research aimed explicitly at implementing IB approaches to teaching has shown that teachers, especially trainee teachers, often do not fully succeed in passing from a "transfer of knowledge-type" of teaching to an IB one if this type of teaching is simply described to them (Pintò, 2004). They need complete training based on the new theoretical models referred to. These include models that underline the usefulness of a shared process of constructing knowledge, sharing it again in different contexts, thinking about developing new teaching practices, and new support materials for the students. These models require careful planning of the training activities, during which the roles of different learning materials, the conceptual knots of the subject, the problems that arise from the introduction of new teaching methods, the teacher conceptions on the teaching processes (Fazio & Spagnolo, 2008) and, more generally, the ideas of the teachers on their role in the learning process are discussed and made clear.

Research Problem

Based on the considerations described above, this study seeks to investigate ideas and beliefs of trainee elementary school teachers about science and their ability to teach scientific subjects effectively, and the possible effects of "traditional" and inquiry-based workshops of the modifications of these ideas and beliefs.

Research Hypothesis

Trainee teachers of the Physics for Elementary School course at the University of Palermo, Italy generally have low levels of science teaching efficacy beliefs,

which are reflected in the scarce perception of the relevance of science in real-life and low attitude to teaching scientific subjects at school.

Research Questions

- To what extent can a teaching workshop based on the application of methods and concepts learned by the trainee teachers in their introductory university courses on didactics and pedagogy be useful in modifying their ideas about teaching science at Elementary School and their science teaching efficacy beliefs?
- To what extent can a teaching workshop based on implementing IB methods and sharing results with peers be useful in modifying trainee teachers' ideas about teaching science at Elementary School and their science teaching efficacy beliefs?

Context and Participants

The research was carried out during the 2018-19 academic year at the Elementary Teacher Education Degree Course at the University of Palermo, Italy, and it involved 150 trainee teachers from the fourth year of the Degree Course, mainly females, who were attending the Physics for Elementary School course, which is taught by one of the authors. Many of them attended secondary schools where physics is usually taught by following a traditional, teacher-centered approach, and where physics teaching is mainly based on the transmission of general concepts to students. In some cases, the lessons are integrated with laboratory activities, but these are often performed by the teachers themselves, who follow a confirmatory/demonstrative approach. During the first years of the degree course, the trainee teachers attended several theoretical courses of Pedagogy, Didactics, and Psychology of Education.

Methodology

The research was divided into the following stages:

- The trainee teachers were given a pre-instruction questionnaire to test their initial ideas about teaching science in elementary schools. It was based on questions from questionnaires used in some of the FP7 projects mentioned before, modified and validated by specific content and face validation (e.g., Lawshe, 1975; Anastasi, 1988) in order to adapt them to the specific context of the research being carried out; Particularly, the face validation of the questionnaire was done by involving seven trainee teachers of the Physics for Elementary School course that, for various reasons, did not participate to the research. They were asked to answer the questionnaire, highlighting sentences or whole questions that were

unclear to them, and suggesting modifications that would improve the understandability of the questions. A face-to-face interview with each student participating in the questionnaire validation completed the procedure.

- A "traditional" teaching workshop was carried out, based on the Italian National Guidelines for Elementary School and the application of concepts learned by the trainee teachers in their introductory university courses on Pedagogy and Didactics. The focus was on planning science teaching pathways for elementary school children under the supervision of experienced Elementary School teachers. Working in groups, producing and discussing working material based on teaching methods learned during previous courses were fundamental aspects of the workshop;
- At the end of the traditional workshop, the trainee teachers completed the same questionnaire again, as an intermediate test;
- A teaching workshop based on an IB approach, on groups work, on a peer-to-peer sharing of the group results was carried out, and a science exhibition event for elementary school children was planned and carried out;
- At the end of the science exhibition event, the trainee teachers completed the questionnaire for the last time.

As well as being asked to complete the questionnaire repeatedly, some trainee teachers were also interviewed before, during, and after the teaching activities, and the work materials they produced were analyzed (Heath et al., 2010).

The activities of the "traditional" teaching laboratory were carried out in four sessions, each four hours long. The 150 trainee teachers participating in the traditional teaching workshop were divided into six groups of twenty-five people, each coordinated by an experienced Elementary School teacher.

During the first session, the trainee teachers participated in a focus group to study their ideas about how a teaching workshop should be organized. Moreover, they analyzed the National Guidelines for Elementary Schools in detail, discussing in small groups, sharing their opinions, and producing written reports of their group discussions.

During the second session, the trainee teachers were asked to plan some teaching pathways for physics content, based on knowledge and teaching methods they were exposed to when they were at school, and during their university career. This entailed putting into practice the teaching methods learned during the introductory university courses, applying them to science subjects. However, no explicit reference to a

specific educational reconstruction of the content to be taught was requested.

The third session was spent preparing mind maps, posters, and other teaching tools for the selected pathways, as learned during the introductory university courses on Didactics and Teaching Methodology.

In the fourth session, the pathways were presented to the experienced teachers supervising the groups and discussed with the other students.

The IB teaching workshop took place about one month after the end of the traditional one. It was not compulsory, but the trainee teachers were advised to attend it. It was made up of four sessions, each of which lasted four hours, and 109 of the 150 trainee teachers involved in the first workshop participated in it. Based on the general introduction to IB teaching approaches, given by the lecturer of the Physics for Elementary Schools Course as part of the curricular activities, the trainee teachers planned some teaching activities that focused on scientific investigation and discovery.

They planned and carried out the simple experiments involved in their teaching activities, focusing on specific issues they considered relevant for teaching. Particularly, they tried to analyze and "use" the difficulties they had when studying the subjects and doing the experiments, as well as the problems they had related to learning, to construct didactic activities that were centered on the children and active learning. These phases were essential for the trainee teachers, also because they allowed them to focus on metareflection as the key to getting them to learn with greater understanding. For metareflection, we mean the activation of those procedures that direct the information processing-flow of learning to make them explicit, recognizable, and reproducible (Simons, 1996). More specifically, we mean the meta-learning development of Schön's (1988) reflective practice. In his classic study, Schön argued that all aspects of teaching-practice supervision should be characterized by the fundamentals of 'coaching' where:

through advice, criticism, description, demonstration, and questioning, one person helps another to learn practice reflective teaching in the context of doing. And one does so through a Hall-of-Mirrors: demonstrating reflective teaching in the very process of trying to help the other learn to do it.

Schön defines the learning activities as the processes of making sense of complexity or reflection-in-action. Notably, he introduces a second reflective domain relevant to the objective of learning to teach: the reflection-on-action, i.e., the thought used to review

the complex teaching/learning interaction by making sense of it.

During the IB teaching workshop, the trainee teachers focused on the conceptual knots of the topics chosen, employing repeated in-group discussions. The lecturer provided 40 experiment kits for the groups of trainee teachers. Each kit was made up of "simple" materials that are easy to obtain, with a total cost of a couple of hundred euros. The planning and carrying out phase of the scientific experiments turned out to be very stimulating for the trainee teachers, many of whom had never worked on the actual construction of scientific experiments or the interpretation of their results. The lecturer provided the trainee teachers with a "workshop exercise book" containing questions and suggestions aimed at encouraging full use of the "5Es" in the IBSE teaching approach (e.g., Bybee et al., 2006). During the activities, the trainee teachers came up with simple but engaging activities for themselves and for their future pupils, found in books and browsing the Internet for resources (YouTube was the favorite one, as it allowed students to see how the experimental apparatuses should be built and used). Finally, they used the results to construct their teaching plans. They then planned a five-day science fair during which they were the facilitators of the activities for elementary school children, specially invited to the event. The science fair took place in the first days of June 2019 at the Department of Physics and Chemistry at the University of Palermo, Italy. Around 500 children participated, accompanied by their teachers and many parents.

Methods

Data Collection and Analysis

Data were collected utilizing the previously mentioned questionnaire and interviews. The typical answers given by the trainee teachers to each question during the three tests are shown in the Appendix. Because the number of trainee teachers that could be classified in the final test was 102, the same number was also used for the initial and intermediate tests.

Data from the trainee teachers' answers to the three tests (pre-instruction, intermediate, and post-instruction) were quantitatively analyzed by CIA. In this study, we used a non-hierarchical clustering method, called k-means (MacQueen, 1967). It allows the researcher to individuate clusters that are also easily represented in Cartesian graphical form. It also allows the researcher to highlight profiles that can characterize the cluster, describing the trainee teachers sample without any prior knowledge of what forms those clusters should take (unsupervised classification).

Classification of student answers to the questionnaire Due to the open nature of the questions (reported in the Appendix), a procedure described in the literature (Battaglia et al., 2019b) aimed at coding trainee teachers' answers to open-ended questions was followed. At the end of it, a shared list of 63 typical answers² given by the trainee teachers when tackling the pre-instruction questions was obtained. This list was supplemented by some other typical answers given in the post-instruction test. It was used, in its final form of 65 typical answers, for the coding of answers in all the three tests³, taking into account the full spectrum of different trainee teachers' answers.

Once the typical answers have been shared and agreed among the researchers, each researcher reread the trainee teachers' records and assigned each answer to a given question to a specific typical answer. Given the inevitable differences among the researchers' interpretations, the three lists were compared and contrasted in order to get to a single agreed list. No answer was discarded at the end of this phase. Discordances between researcher lists were usually a consequence of different researchers' interpretations of trainee teachers' statements. This happened 40 times when comparing tables of researchers 1 and 2, 17 times for researchers 1 and 3, and 29 times for researchers 2 and 3. Hence we obtained excellent percentages of accordance between the analysis tables of each researcher pair.

Trainee teachers' answers to pre-, intermediate, and post-instruction questionnaires were coded by using a binary scheme⁴. Each trainee teacher, i , was identified in the three tests by arrays a_i , a'_i and a''_i , composed of 65 components 1 and 0, respectively, resuming the answers given by him/her in the questionnaire.

Cluster Analysis

CIA methods are commonly used to generate groupings of a sample of elements (in our case, trainee teachers) by partitioning it and producing a smaller set of q non-overlapping clusters. Among the currently used algorithms, we applied the k -means one, which was proposed by MacQueen in 1967. The metric we used is Gower's one (1966), as it appears to be well fitted to the use in Educational Research (Battaglia et al., 2019b). All the clustering calculations on the data coming from the submission of the questionnaires to trainee teachers were performed using custom software, written in C language. The graphical representations of clusters were obtained using the well-known MATLAB software (2015).

To define the number q of clusters that best partitions our samples in all the three tests, the mean value of the Silhouette function (Rouseeuw, 1987), $\langle S(q) \rangle$ was

calculated for different numbers of clusters. We found that the best partitions of our samples were achieved by choosing $q=4$ clusters in the pre-, intermediate, and post-instruction tests ($\langle S(4) \rangle = 0.78$ (C.I.= 0.74-0.81), 0.77 (C.I.= 0.73-0.80), and 0.79 (C.I.= 0.75-0.82), respectively)⁵. The obtained values were all higher than 0.6, indicating that reasonable cluster structures have been found (Struyf et al., 1997).

Once the appropriate partition of data has been found, each cluster was characterized in terms of trainee teachers' behavior. To do this, we took into account the typical answers most frequently used by the cluster trainee teachers, which, according to Springuel et al. (2007), can be called the "prominent" answers.

Like all the other cluster elements (the trainee teachers), each cluster centroid, C_k ($k=1,2,3,4$), can be represented by an array composed of 65 0 and 1 components. It is worth noting that C_k has a remarkable feature: \bar{a}_k contains 1 values right in correspondence of the typical answers most frequently used by the cluster trainee teachers (Battaglia et al., 2019b). This feature allowed us to give meaning to the cluster centroid as the element that characterizes the cluster in the sense we discussed above.

Therefore, in each test, the four clusters Cl_1 , Cl_2 , Cl_3 , Cl_4 could be characterized by their related centroids, Cl_{1r} , Cl_{2r} , Cl_{3r} , Cl_{4r} , respectively (see Tables 1-3. The codes used in the tables refer to the typical answers used by the trainee teachers, as described in the Appendix).

Qualitative Analysis of Other Data

More data were collected using semi-structured interviews with some of the trainee teachers before and after they participated in the IB workshop and to the science fair. The teaching plans made by the trainee teachers during the traditional teaching workshop activity were also used as a source of data. The interview protocols were pre-designed by the researchers, and the interviews were conducted by one of them in a face to face set-up with the trainee teacher being interviewed. In line with semi-structured interview methodology, questions not in the interview protocol were also asked to clarify better specific situations emerging during the discussion.

In this paper, we will report some preliminary analysis of the data we collected to give some more fine-grain detail about the results obtained using the cluster analysis of trainee teachers' answers to the questionnaire. A more in-depth analysis of the qualitative data is in progress and will be discussed in a forthcoming paper.

Results

The results of CIA of the answers given to the questions in the pre-test by the trainee teachers in our sample are shown in Figure 1, where four clusters, and the related centroids (circles), are recognizable.

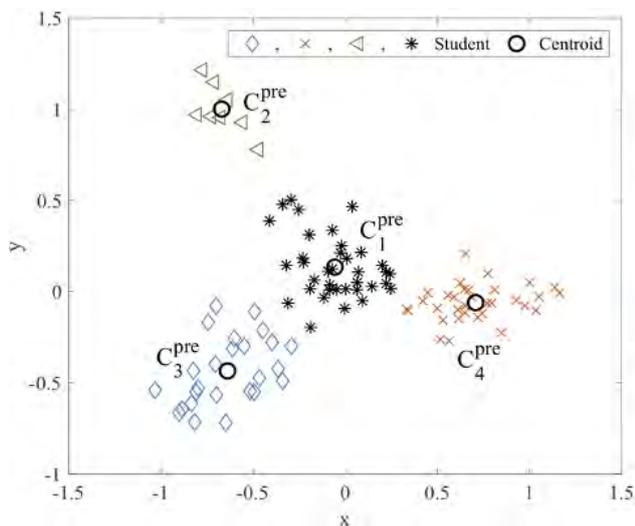


Figure 1. The results of the clusters analysis of the answers to the initial questionnaire represented in a Voronoi diagram. The Cartesian axes simply show the values necessary to identify the position of the various points based on their mutual distance

Each point in Figure 1 represents a trainee teacher, and it is placed on the diagram based on the "distance" from each other trainee teacher. The distance between one trainee teacher and another is calculated using the relative coefficient of correlation between the two, calculated based on the answers given by them to the questions in the questionnaire (Battaglia, et al., 2019b). The Cartesian axes simply show the values necessary to identify the position of the various points (the trainee teachers in the sample) based on their mutual distance⁶.

Table 1 summarizes the answers most frequently given by the trainee teachers in each cluster (i.e., the components of the related centroids). It follows the coding used in the Appendix. The number of trainee teachers in the clusters, and other quantities relevant for the cluster solution, are also shown. Particularly, the average values of the Silhouette function for each cluster show to what extent the cluster elements are tightly arranged in the cluster and are distinct from elements of the other clusters (Rouseeuw, 1987). The reliability coefficient value can give information on how well a centroid characterizes its cluster. This value increases when the cluster elements decrease and when the cluster average silhouette value increases. In our case, the higher the reliability coefficient of a cluster, the more trainee teachers in the cluster give

answers to the questionnaire not much differentiated from each other and from those of the centroid. More detail can be found in Battaglia et al. (2019b)

Table 1. Typical answers that are most frequently given by the trainee teachers during the initial test, and other quantities for each cluster. The typical answers are shown using the coding reported in the Appendix

Cluster centroid	C1	C2	C3	C4
Most frequently given answers	1.f, 2.a, 3.f, 4.b, 5.a, 6.a, 7.a, 8.a, 9.e, 10.c	1.b, 2.e, 3.f, 4.b, 5.a, 6.a, 7.a, 8.a, 9.e, 10.c	1.e, 2.e, 3.b, 4.b, 5.a, 6.a, 7.c, 8.e, 9.c, 10.c	1.b, 2.c, 3.c, 4.d, 5.b, 6.b, 7.e, 8.c, 9.f, 10.a
Number of trainee teachers	36	8	25	33
Silhouette average value	0.72	0.94	0.76	0.81
Reliability coefficient	0.07	1.95	0.12	0.13

A first result emerging from the first three components of all the four cluster arrays in Table 1 shows that our sample is quite aware of the importance of teaching science in elementary school and developing thinking and reasoning processes. They also mainly think that children must be aware of the aspects of science that relate to everyday life. However, the majority of trainee teachers in clusters 1, 2, and 3 think that teachers are not always able to encourage pupils to discuss scientific topics related to everyday life because they feel to be not adequately prepared. Moreover, they think that elementary school children do not ask themselves questions about the world because they are too young.

Specific tendencies in each cluster are identifiable, as can be seen from the answers to questions 7 to 10. Notably, trainee teachers in clusters 1 and 2:

- think that teachers can easily run science workshops with their pupils only if they are well prepared and motivated;
- think that it is not easy to ask pupils questions aimed at improving their thinking skills;
- are not very convinced about their preparation to plan a scientific activity for their pupils;
- think it is not possible to choose a topic to study with children because they are too young;

trainee teachers in cluster 3:

- think that teachers cannot easily run science workshops with their pupils because schools often lack resources;
- think that it is possible to ask pupils questions aimed at improving their thinking skills if the everyday experience is at first referenced;

- do not like the idea of planning a scientific activity in class as they do not like science.
- think it is not possible to choose a topic to study with children because they are too young;

trainee teachers in cluster 4:

- think that teachers cannot easily run science workshops with their pupils because it is necessary to find suitable activities;
- only a competent teacher can easily ask pupils questions aimed at improving their thinking skills;
- like the idea to plan a scientific activity in class because this can be a way to put what they have studied into practice;
- think it is not possible to choose a topic to study with children, but it is possible to guide their choices.

Figure 2 shows the results obtained from the analysis of the trainee teachers' answers to the questionnaire given to them after the completion of the "traditional" type teaching workshop.

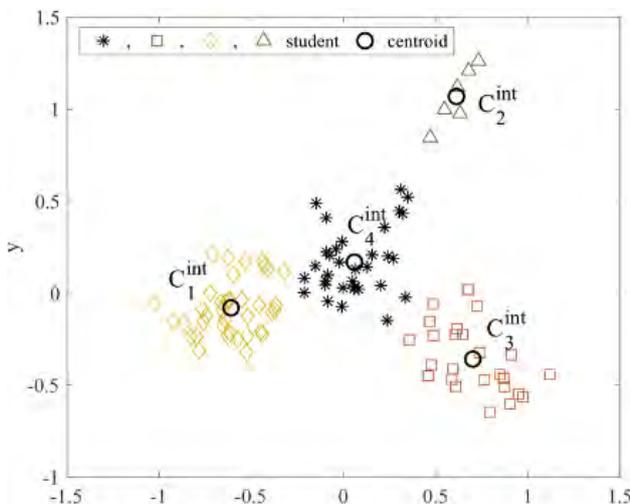


Figure 2. The results of the clusters analysis of the answers to the intermediate questionnaire, represented in a Voronoi diagram.

Again, the k-means algorithm identifies 4 clusters as the best partition of the 102 trainee teachers, and Table 2 summarizes the answers most frequently given by the trainee teachers in each cluster and the number of trainee teachers in the clusters.

A comparison between the clusters formed as a result of the analysis of initial and intermediate tests shows that they have a different form and, in some cases, different numbers of elements. However, the answers most frequently given in the intermediate test are still

substantially the same as before. This means that the trainee teachers' ideas regarding the importance of teaching science subjects and their self-perceived skills and difficulties in planning science lessons and deal with scientific subjects during a lesson did not change much between the two sessions of the questionnaire.

Table 2. Typical answers that are most frequently given by the trainee teachers during the intermediate test, and other quantities for each cluster

Cluster centroid	C1	C2	C3	C4
Most frequently given answers	1.b, 2.c, 3.c, 4.d, 5.b, 6.b, 7.e, 8.c, 9.e-f, 10.a	1.b, 2.e, 3.f, 4.b, 5.a, 6.a, 7.a, 8.a, 9.e, 10.c	1.e, 2.e, 3.b, 4.b, 5.a, 6.a, 7.c, 8.e, 9.c, 10.c	1.f, 2.a, 3.f, 4.b, 5.a, 6.a, 7.a, 8.a, 9.e, 10.c
Number of trainee teachers	38	6	25	33
Silhouette average value	0.80	0.94	0.77	0.69
Reliability coefficient	0.11	2.45	0.14	0.07

Finally, Figure 3 shows the results obtained from the analysis of the trainee teachers' answers to the questionnaire given to them after completion of the IB-type teaching workshop.

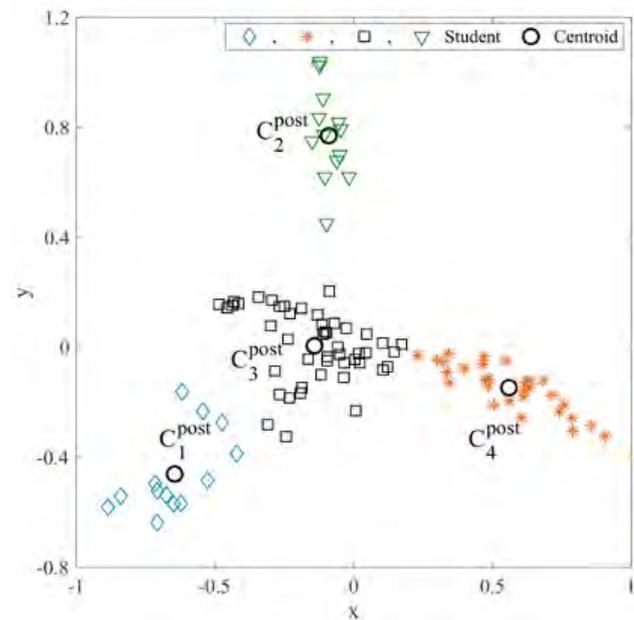


Figure 3. The results of the clusters analysis of the answers to the final test, represented in a Voronoi diagram

Once again, the k-means algorithm identifies 4 clusters as the best partition of the 102 trainee teachers. Table 3 summarizes the answers most frequently given by the trainee teachers in each cluster and the number of trainee teachers in the clusters

Table 3. Typical answers that are most frequently given by the trainee teachers during the final test, and other quantities for each cluster. Note that trainee teachers in cluster 2 never answered question

Cluster centroid	C1	C2	C3	C4
Most frequently given answers	1.c, 2.d, 3.d, 4.g, 5.f, 6.c, 7.f, 8.e, 9.f, 10.f	1.g, 2.a, 3.h, 4.a, 5.d, 6.d, 7.g, 8.-, 9.e, 10.b	1.c, 2.b, 3.d, 4.g, 5.a, 6.c, 7.f, 8.d, 9.h, 10.f	1.b, 2.b, 3.d, 4.b, 5.e, 6.a, 7.a, 8.a, 9.f, 10.d
Number of trainee teachers	13	13	47	29
Silhouette average value	0.80	0.89	0.74	0.82
Reliability coefficient	0.31	0.61	0.06	0.16

The results of the analysis are now considerably different from the ones obtained during the two previous tests. Opinions about the importance of teaching science at elementary school are still very positive, but now:

trainee teachers in cluster 1:

- think that it is possible to encourage pupils to discuss scientific topics to promote active learning;
- think that children must be aware of science in their everyday life to improve active learning;
- acknowledge that pupils are curious by nature;
- think that it is not difficult to run a science workshop;
- believe that in asking scientific questions is always necessary to start from everyday experience
- feel that planning a scientific activity for pupils can allow them to put what they studied into practice;
- acknowledge that choosing a topic to study with pupils can allow them to have an active role in their learning;

trainee teachers in cluster 2:

- think that it is possible to encourage pupils to discuss scientific topics to foster the sharing of information
- think that children must be aware of science in their everyday life to answer their questions;
- think that it is possible to run a science workshop because pupils learn by doing;
- still do not feel to be adequately prepared to plan a scientific activity for pupils effectively;
- believe that it is the teacher that must conduct the teaching/learning processes;

trainee teachers in cluster 3:

- think that it is possible to encourage pupils to discuss scientific topics to promote active learning;
- think that to be aware of science in everyday life can improve pupils' general knowledge;
- acknowledge that pupils are curious by nature;
- think that it is not difficult to run a science workshop, as a few materials are required;
- believe that it is natural for children to ask many questions about everyday phenomena;
- now understand they can do planning for science subjects, and like it;
- acknowledge that choosing a topic to study with pupils can allow them to have an active role in their learning;

trainee teachers in cluster 4:

- still think that teachers are often not adequately prepared to encourage scientific discussion in class;
- think that to be aware of science in everyday life can improve pupils' reasoning;
- believe that pupils are too young to ask themselves questions about the world;
- believe that to run a science workshop, teachers must be well prepared and motivated;
- think that children do not reflect too much, as they are too young;
- like to plan a scientific activity to put what they have studied into practice;
- think that it is possible to choose with pupils some topic to study;

Most trainee teachers have noticeably changed their ideas about their abilities and the possibility of teaching science using a workshop approach. However, some of the trainee teachers in cluster 2 still do not feel to be adequately prepared to effectively plan a scientific activity for pupils and think that a lesson should be mainly the responsibility of the teacher. Moreover, some of the trainee teachers in cluster 4 still have concerns about the teacher preparation and motivation to run scientific activities and children's disposition to ask questions about the world and reflect.

More information can be gained by means of a preliminary qualitative analysis of interviews conducted with some of the trainee teachers before they participated in the IB workshop and to the science

fair. These interviews confirm that after the traditional workshop, many of the trainee teachers involved in the research were perplexed about their own ability to plan laboratory activities for science teaching in a school setting (e.g., "I am not theoretically prepared to teach physics"; "I never did physics laboratory during my school years"; "A well-equipped laboratory is necessary, and our schools very often do not have even simple laboratories"; "Very rarely there is money available in schools to buy complex equipment"). This is significantly related to the presumed complexity of carrying out "real scientific experiments", as well as the need for adequate space and considerable funds to carry out the lab activities properly, something very often lacking in Italian elementary schools.

A preliminary analysis was also made of the teaching plans made by the trainee teachers during the "traditional" teaching workshop activity. It demonstrates that the trainee teachers often refer to a "workshop method" with explicit reference to what they have studied in their university courses in teaching. In fact, during their theoretical studies of pedagogy and didactics, the trainee teachers have been taught that a workshop is a "mental place or space" where children not only acquire knowledge and abilities but also specific skills (e.g., "Laboratory should not be a physical place, but a mental habit"; "The workshop method is a way to actively involve pupils in their learning, preferably by using objects we find around us"; "During workshop activities, pupils can do things, discuss, be involved in reflecting and developing their skills"). Cognitive involvement is often mentioned as one of the possibilities offered by a workshop. However, then the actual teaching plans often leave little space for dialogue, discussion, suggesting theories and solutions or metacognition. This often leads to planning in which workshops are too attached to operational and tangible aspects and have little to do with the reflective and cognitive spheres. This betrays the deeper meaning of the idea behind teaching workshops in schools, which is to promote active and authentic learning of pupils.

The results of the preliminary qualitative analysis of the data we gathered after the IB activities and the science fair (interviews and plans for the science fair) show that actively attending an IB teaching workshop, sharing the results with peers, and exhibiting the workshop products in a didactic environment with real children, seems to give trainee teachers faith in their possibility to teach science subjects and an "in the field" understanding of the importance of meta-thinking in workshops. (e.g., "The possibility I had to build simple experiments, reflect on their meaning, discuss them with my classmates and to use them

during the science fair convinced me that I can plan a science workshop"; "Searching on the internet for possible experiments, looking for simple material to build them and discussing with my mates was great for my understanding of the subjects"; "I was amazed by the questions raised by children during the science fair days, and by the many ideas they gave us about improving the experiments we proposed them"). The IB teaching workshop also provides trainee teachers with planning models that they can apply, reflecting on their understanding and their learning about the science topics in their teaching plans. The trainee teachers who were interviewed clearly stated that the inquiry approach, which is well known for motivating pupils in schools, was also significant for them. They reckon that it improved their planning abilities and helped them to plan teaching activities based on the natural learning phases of a human being (i.e., the "learning by discovery" concept, that was repeatedly proposed to them during their theoretical lessons in pedagogy, but they were seldom able to experiment on the building of their knowledge and of pupils' one), without neglecting either the operational aspect or the thinking aspect typical of problem-solving activities.

After the IB activities, many trainee teachers also recognized, sometimes with amazement, that it is possible to do scientific experiments in spaces that are not specifically equipped for the purpose, with inexpensive everyday materials (e.g. "From this experience I learned that I can arrange an experiment on a complex topic like friction forces by just using sheets of various materials, a plastic bag and other objects found in real life"; "Now I know that a complete physics laboratory is not needed at all! All I need is low-cost objects that pupils can also find in their homes"). The prejudice demonstrated before, about the difficulty of carrying out science workshop activities in schools, because of a lack of equipment and funds and the absence of a real science laboratory, was now much less frequent.

However, some trainee teachers still held onto the idea that setting up an investigative science workshop was a complicated task and that very formal and "serious" skills (knowledge of mathematics and science superior to that which they possessed) were essential (e.g., "I still need to know mathematics to teach science subjects effectively"; "My overall understanding of physical laws is incomplete. I need to improve it to organize a science workshop effectively"). They still believed that without these skills, it would be difficult to organize significant science workshop activities, regardless of the spaces, funds, and equipment available in the school.

Discussion

This study investigated the hypothesis that trainee teachers of the Physics for Elementary School course at the University of Palermo, Italy have low levels of science teaching efficacy beliefs, which are reflected in the poor perception of the relevance of science in real-life and low attitude to teaching scientific subjects at the elementary level.

The results of the cluster analysis of the answers given by the trainee teachers to the questions in the initial questionnaire and the preliminary qualitative analysis of interviews conducted with some of them confirm the research hypothesis. The trainee teachers admit the importance of teaching scientific subjects in elementary school and preschool, but the beliefs about their ability to effectively teach science are quite negative.

There is consensus among researchers that highly self-efficacious teachers are more prone to be innovative with their teaching strategies (Marshal, 2009; Deemer, 2004). Moreover, they tend to reflect more on planning their science lessons and finding suitable materials for constructing didactic activities that can be meaningful for students (Deemer, 2004). Therefore, a low level of science teaching efficacy beliefs should be a concern to educators, and particularly to lecturers of pre-service teacher education degree courses.

To tackle such a situation, it is important to identify reasons for the low science teaching efficacy beliefs of so many trainee teachers. A possible one is found in considering that many of them attended secondary schools where physics is usually taught by following a traditional, teacher-centered approach, and where physics teaching is mainly based on the transmission of general concepts to students. This experience of secondary school science might not have encouraged the development of positive attitudes to scientific subjects and science teaching. In 2007 Bleichner confirmed that the low science conceptual understanding of pre-service elementary teachers contributes to the development of low science teaching efficacy beliefs. According to Samuel (2017), traditional teaching practices at secondary schools are responsible for students portraying science subjects as difficult and unappealing.

The data we collected after the traditional workshop clearly show that the low level of trainee teachers' beliefs about their ability to teach science effectively is not much changed after that kind of instruction. As we have seen, many of the trainee teachers still believe that science workshop activities are challenging to put into practice, both for objective reasons beyond teachers' control (i.e., lack of resources and support

from the school management) and their lack of skills and that of schoolteachers in general. There is also an evident lack of faith that children will be able to understand and carry out activities considered difficult because related to Physics. On the positive side, they think that simple topics suitable for scientific discovery and investigation activities can still be proposed.

Based on these results, we can answer our first research question. A teaching workshop based on traditional methods is not sensibly effective in modifying trainee teachers' ideas about their science teaching efficacy beliefs, and, more generally, about teaching science at elementary school, even if experienced elementary school teachers tutored the trainee teachers. This is a result documented in the literature, where traditional teacher training is credited to make often trainee students feel a disconnection between the theories they study in their university courses and the practice the experienced teachers ask them to apply in their didactic projects (Assadi et al., 2019). Yue & Liu (2019) pointed out that teachers trained traditionally may feel that such kind of training is not effective or targeted, or show difficulty in scientifically tackling real-life situations (Ernest, 1989). More generally, Ginns and Walters (1998) showed that teacher education programs based on a traditional approach hardly result in improvements in teachers' science teaching efficacy beliefs.

The cluster analysis of the answers given to the questionnaire after doing the IB teaching workshop and holding several days of science fairs and the qualitative data gathered show, on the other hand, that most of the trainee teachers' negative beliefs about teaching science seem to have changed into positive ones. This result allows us to answer to our second research question, highlighting some benefits of an approach to teacher education based on inquiry and discovery, on sharing results with peers, planning and attending a science fair, and on metareflection on learning processes. Particularly, it appears that such a structured approach favors a better general understanding of the fundamental role played by the teacher in encouraging the natural curiosity of children, and offering scientific activities based on everyday life experiences was observed. Moreover, the "alibi" of the lack of resources in schools, which was initially given as an obstacle to teaching based on scientific workshops, is also put into perspective. Finally, faith that children can ask themselves questions about the world around them, and learn to reason and think, increases considerably.

Several researchers noted that involvement in active teacher training activities, where pedagogy content is strictly related to the specific didactical context, in sharing results with peers and other people, and in

meta-reflecting on learning processes might have a positive effect in developing positive attitudes toward teaching. Hechter (2011) showed that integrating subject matter content and contextualized pedagogic methods in courses results in improved perceptions of science teaching efficacy. Mbowane et al. (2017) showed that teacher participation in science fairs can contribute to the building of pedagogical knowledge, content knowledge (both procedural and declarative or factual knowledge), and pedagogical content knowledge. Moreover, according to these authors, planning and participating in a science fair can improve self-efficacy beliefs, develop strengthened, positive attitudes towards science, and strategies of inquiry-based learning and effective methodological instruction, which can contribute to the participants' school-based teaching. Finally, Plourde (2002) argued that engaging trainee teachers in teaching experiences in which they are encouraged to reflect on their conceptual understanding, and then compare and contrast with peers their beliefs about science and teaching science may be a winning solution for the development of positive beliefs about science teaching. Plourde's argumentations are well related to the idea of meta-learning development of Schön's (1988) reflective practice we cited above.

Conclusions

Our findings, mainly based on cluster analysis of the answers given by the students to a questionnaire submitted to them before a "traditional" teaching workshop, immediately after it, and again after an IB workshop and a science fair, confirm, first of all, the hypothesis that the trainee teachers of the Physics for Elementary School course at the University of Palermo, Italy generally have low levels of science teaching efficacy beliefs. This result is probably expected, given the poor science background of the majority of the trainee teachers, mainly shaped by years of traditional, teacher-centered didactic activities, where physics and, more generally, science teaching is mainly based on the transmission of general concepts to students.

A comparison between the clusters obtained after the first administration of the questionnaire to the trainee teachers, and the intermediate one, also show that a teaching workshop based on the mere application of methods and concepts that the trainee teachers are supposed to have learned in their introductory university courses on didactics and pedagogy has not practical effects in modifying trainee teachers' ideas about science teaching efficacy beliefs and, more generally, about the possibility to teach science at Elementary School effectively. Notably, many trainee teachers: i. find it difficult to discuss the physics/science behind real-life situations, mainly because they feel not to be adequately confident with such

subjects; ii. think that children attending the first years of elementary school are too young to be able to ask themselves questions about the world; iii. feel that it is not easy to run science workshops with their future pupils because schools often lack adequate laboratory resources; iv. do not like the idea to plan a scientific activity in class as they do not like science; v. find difficult choosing a topic to study with pupils because they are "too young".

On the other hand, after attending the IB workshop and organizing a science fair, the trainee teachers highlight positive evolution of their science teaching efficacy beliefs and also more faith in the capabilities of young pupils to approach science subjects at elementary school. Particularly, many of them: i. think that it is not so difficult to run a science workshop, mostly because expensive laboratory tools are not at all needed to organize them; ii. acknowledge that choosing a topic to study with pupils may allow them to have an active role in their learning; iii. Feel confident in their capability to plan and run science activities, recognizing that, yes, they also like them; iv. feel that planning a scientific activity for pupils can allow them to put what they studied into practice, especially concerning the theoretical contents regarding general pedagogy and didactics.

Not all the trainee teachers show such a straightforward modification in their ideas and beliefs about science and teaching it. Some are still dubious about their real preparation with scientific subjects and think they must deepen their science understanding to teach. However, the general science teaching efficacy beliefs are indeed at a higher level than before IB instruction.

These findings show that an approach to pre-service elementary teacher education based on active learning, on metareflection, and on sharing results, even planning science fairs, can have sensible effects on how trainee teachers plan for their future classroom activities and practices and shape their behavior during classes. A pre-service elementary teacher education program based on developing scientific investigation and discovery processes, and focused on metareflection may be a way to redirect trainee teachers' beliefs about science and science teaching, improving understanding of the sciences and their working methods

This study has some limitations. The first and more evident is the relatively low number of trainee teachers involved in the IB teaching workshop (about 2/3 of the ones involved in the traditional workshop). Another limitation of this study is strictly related to the cluster analysis method. It is well suited to make emerging typical characteristics of a group (the trainee teachers

profiles defined by the centroids) but is not able to give precise detail on the behavior of each single trainee teachers. To overcome this limitation, accurate analysis of the answers given by each trainee teacher to the questionnaires is necessary, adding a qualitative analysis of the interviews taken with some of the trainee teachers. Particularly, it could be interesting to perform a more in-depth study on the trainee teachers that after the IB workshop did not highlight sensible changes in their beliefs about science and teaching science, to try to understand what can be the reasons for those results. We hypothesize that the short duration of the workshop could be one of those reasons, as a more extensive training program than that which was possible during the study described here could have led more trainee teachers to activate a "conceptual change" (e.g., Vosniadou (Ed.), 2008) with respect their beliefs about science and science teaching.

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Appendix

Questions in the questionnaire and typical answers given by the students

- Do you think it is important to deal with topics of a scientific nature with elementary school children? Explain your answer.
 - Yes, because it can be done using simple experiments.
 - Yes, in order to create a solid base for future studies.
 - Yes, to promote cognitive abilities.
 - Yes, because they are very curious at that age.
 - Yes, so that they understand the world around them.
 - Yes, even if they are very young.
 - Yes, to encourage scientific language.
- Do you think it is important to develop thinking and reasoning processes in elementary school children? Explain your answer.
 - Yes, because they are difficult processes and children need to learn them from a young age.
 - Yes, to develop cognitive abilities.
 - Yes, because children of this age are not used to thinking.
 - Yes, so that they understand the world around them.
 - Yes, for their future cognitive development.
 - Yes, because children are used to thinking and asking themselves thousands of questions
- Do you think good teachers use pupils' questions to guide their teaching of science subjects? Explain your answer.
 - Yes, to allow them to construct their knowledge actively.
 - Yes, but not all of them do it.
 - Yes, because if their curiosity is the starting point, they are motivated to learn.
 - Yes, to promote the transition from common knowledge to a more scientific knowledge, starting from well-known topics.
 - Yes, so that the knowledge is meaningful and useful.
 - Yes, to get them used to ask questions and thinking.
 - Yes, so that the teachers can answer their questions adequately.
 - Yes, to find out their prerequisites and start from those.
- Do you think good teachers encourage students to discuss scientific topics related to everyday life? Explain your answer.
 - Yes, to encourage the sharing of information.
 - No, because teachers are often not adequately prepared to do it.
 - Yes, to start from practical knowledge and reach an understanding of the theory.
 - Yes, to stimulate the abilities of thinking, problem-posing and problem-solving.

- e. Yes, to move easily from theory to practice.
- f. Yes, because science is the study of what happens in the world.
- g. Yes, to improve active learning (only used in the post-instruction test)

5. Do you think it is important for children to be aware of the aspects of science that relate to everyday life? Explain your answer.

- a. Yes, to improve their general knowledge.
- b. Yes, because that way they can understand the world around them.
- c. Yes, to be able to appreciate the science that they will study in a school in the future.
- d. Yes, to answer the questions they ask themselves about the world.
- e. Yes, to develop reasoning processes.
- f. Yes, because in this way they can actively learn (only used in the post-instruction test)

6. Do you think elementary school children ask themselves questions about the world?

- a. No, because they are young and often prefer to play
- b. Yes, they try to understand the world around
- c. Yes, because they are curious by nature.
- d. Yes, mainly when they are stimulated by external input

7. How difficult do you think it is for teachers to run science workshops with their pupils? Explain your answer.

- a. It depends on how well prepared and motivated the teachers are.
- b. Not very difficult if the teacher has adequate class management abilities.
- c. Very/quite difficult, because schools often lack resources.
- d. Very/quite difficult. It depends on the classroom context.
- e. Very/quite difficult, because it is necessary to find activities suitable for their age.
- f. Not very difficult, few materials are required.
- g. Not very difficult, because pupils learn by doing.
- h. Very/quite difficult. The teacher needs to be prepared.

8. Do you think it is easy to ask questions that can improve elementary school children's ability to think? Explain your answer.

- a. No. Children do not reflect too much at that age.
- b. No. It depends on the abilities of the teacher.
- c. If the teacher is competent, it is easy.
- d. Yes. Children naturally ask many questions. They are curious.
- e. Yes. It is just necessary to start from everyday experience.

9. Do you like the idea of planning a scientific activity for your pupils? Explain your answer.

- a. Yes, to help the pupils understand that science is important because it relates to the world around us.
- b. Yes, to test myself.
- c. No, I do not like science.
- d. Yes, because it can lead them to theory through practice, starting from the material world.
- e. No, I do not feel well enough prepared

f. Yes, that way I can finally put what I have studied into practice.

- g. Yes, so that they can understand that science is not difficult and therefore become enthusiastic about it.
- h. Yes, because I now understand I can do planning for science subjects, and I like it.

10. Do you think it is possible to choose the topics to study together with the children in elementary school? Explain your answer.

- a. No, but it is possible to guide their choices.
- b. No. It is the teacher that has to have an active role in the teaching-learning process.
- c. No. They are too young.
- d. Yes, it is possible to decide on some topics together.
- e. Yes, because you need to understand what interests them, and know their prerequisites.
- f. Yes. Pupils need to have an active role in the teaching-learning process.