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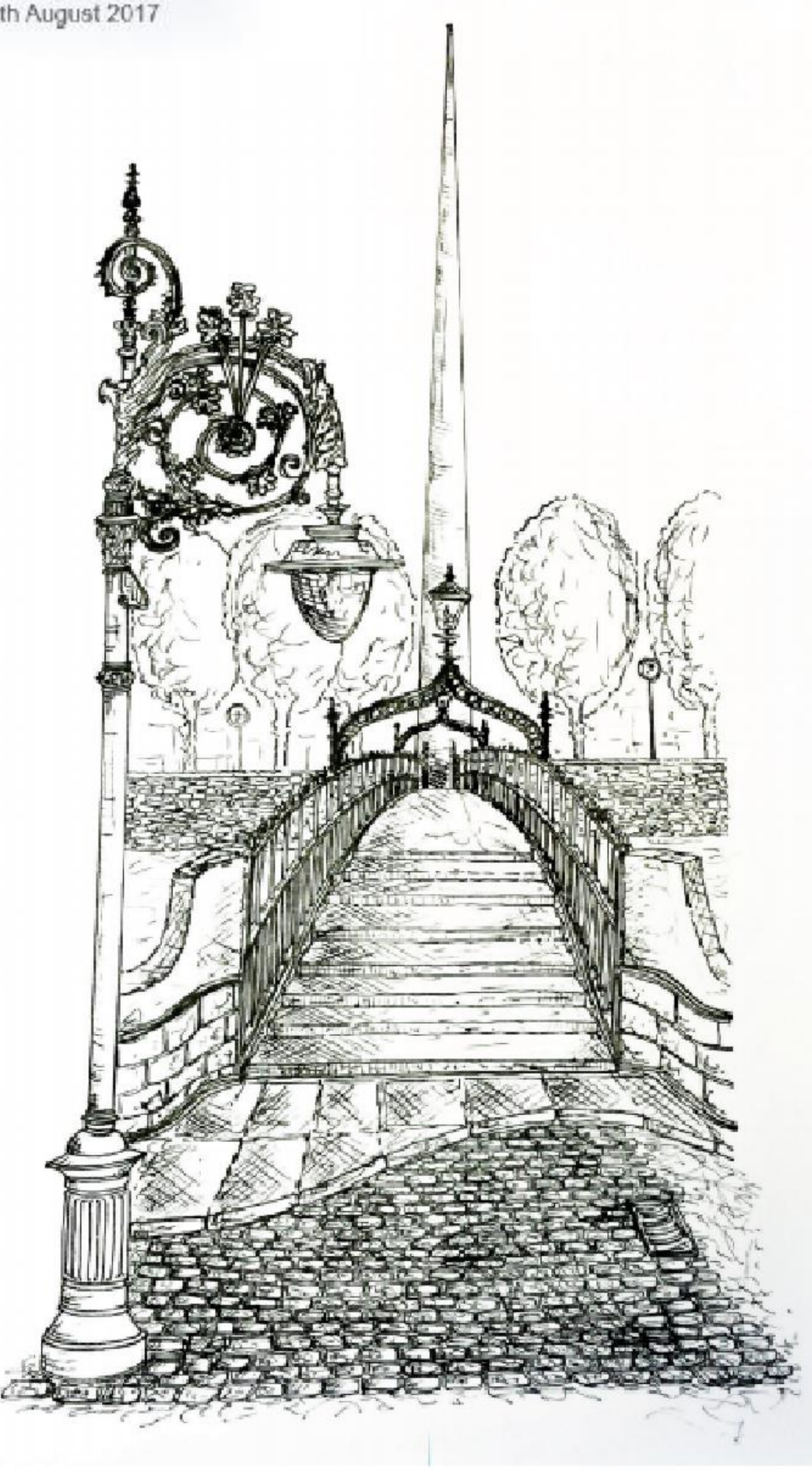

CONFERENCE PROCEEDINGS

Research, Practice and Collaboration in Science Education
Proceedings of the ESERA 2017 Conference

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The Proceedings of ESERA 2017 is an electronic publication for revised and extended papers presented at the ESERA 2017 conference in Dublin, Ireland during the 21-25 August, 2017. All papers in the eProceedings correspond to communications submitted and accepted for the ESERA 2017 conference. All proposals to the conference went through a blind review by two or three reviewers prior to being accepted to the conference. A total of 1246 proposals (out of which 86 were symposia) were presented at the conference and in total 243 papers are included in the eProceedings.

The authors were asked to produce updated versions of their papers and take into account the discussion that took place after the presentation and the suggestions received from other participants at the conference. On the whole, the eProceedings presents a comprehensive overview of ongoing studies in Science Education Research in Europe and beyond. This book represents the current interests and areas of emphasis in the ESERA community at the end of 2017.

The eProceedings book contains eighteen parts that represent papers presented across 18 strands at the ESERA 2017 conference. Part 18 presents papers contributed by ESERA 2016 and 2017 summer school participants that presented at the ESERA 2017 conference. The stand chairs for ESERA 2017 co-edited the corresponding part for each strand 1 to 17 and part 18 was co-edited by the host of the 2016 and 2017 ESERA Summer schools and the coordinating member of ESERA Executive Board. All formats of presentation (single oral, interactive poster, ICT demonstration/workshop and symposium) used during the conference were eligible to be submitted to the eProceedings.

The co-editors carried out a review of the updated versions of the papers that were submitted after the conference at the end of 2017. ESERA, the editors and co-editors do not necessarily endorse or share the ideas and views presented in or implied by the papers included in this book.

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PART 3: STRAND 3

Science Teaching Processes

Co-editors: *Sabine Fechner & Andrée Tiberghien*

CONTENTS

STRAND 3: INTRODUCTION

SCIENCE TEACHING PROCESSES

The contributions to strand 3 "Science Teaching Processes" shed light on current trends in science education research with a focus on the relations between teaching practices and students' cognitive and affective development. In the majority of cases, the projects report on the design of research-based teaching interventions and their role for learning outcomes. Methods are supposed to embrace multiple approaches including video analysis in science education.

The twelve contributions submitted to strand 3 of the ESERA 2017 ebook consist of eleven accounts on research and development projects from all over Europe and Asia as well as a Swedish teacher workshop that was conducted at ESERA 2017 conference. The eleven research and development papers can roughly be divided into three groups with different foci of investigation: While the majority of papers evaluate a novel or adapted teaching intervention and their impact on students, such as different modes of inquiry-based student activity or differentiated learning environments, others focus on teacher competencies and their progression through interventions or relate teacher beliefs and student outcome with each other. Methodologically, the studies show a diverse scope from case studies collecting and interpreting qualitative data to experimental studies with pre-post-test designs using instruments to measure cognitive and/or affective variables.

In terms of teaching approaches, a slight focus can be found on the evaluation of inquiry-based student activities: While the mode of laboratory activity and its effect on student knowledge is investigated in interdependence with teacher beliefs in two papers (Muth & Erb; Weber et al.), a third contribution focuses on the role of teacher feedback during inquiry-based student activities (Eckes & Wilde). The papers report on data that show the effects of the intervention on student affective and cognitive variables while the intervention itself is not monitored by data collection.

Another three papers investigate novel or adapted teaching approaches with the aim of fostering student affective and/or cognitive outcomes. For teaching at school level, a digital educational scenario is presented that aims at motivating interdisciplinary problem-solving on the basis of gamification (Theodoropoulou et al.), while the approach "Ladders of Learning" adapted from India is examined with regard to its potential as a differentiated learning environment (Hauerstein & van Vorst). For higher education, Kraus and colleagues evaluate a physics course on general relativity which focuses on a model-based and conceptual rather than a mathematical approach (Kraus et al.).

It is interesting to note, however, that these studies investigate students' responses to a variety of interventions without investigating the implementation of the actual intervention by means of process analysis. The interplay of student and teacher interaction in the learning process is only observed by one paper (Ha & Kim). They examine teachers' responsive practices to support students' epistemologically productive practices by means of argumentation analysis. The interdependence of teacher beliefs and student outcome is also investigated in a correlational study using quantitative data (Korom et al.). Here, the relationship of teaching strategies and student reasoning skills is reported.

Focusing on the part of the teacher, one paper reports on multiple studies on teacher topic-specific content knowledge in the area of chemical bonding (Rollnick et al.). Eliciting pre-conceptions, the authors report on ways to diagnose and professionally develop scientifically correct views on the topic.

Concerning the used methods, it is striking that little process analysis, such as video-based analysis in the classroom or intervention group, is used to tackle and explain the learning processes that lead to certain student affective or/and cognitive outcomes. On the other hand, a number of papers pursue the goal of explaining the effects of the intervention on students by directly relating it to teacher beliefs such as the preferred teaching strategy investigated through questionnaires.

The combination of papers also underlines the trend that the selection of specific scientific topics for the investigation is not necessarily justified by the authors. The scientific topics rather become a vehicle to study the respective intervention which is often based on general educational principles (e.g., digital learning, feedback). Exceptions can be found in the course on relativity (Kraus et al.) and the symposium paper on chemical bonding (Rollnick et al.).

Sabine Fechner and Andrée Tiberghien

THE EFFECT OF TEACHING STRATEGIES ON 4TH GRADE CHILDREN'S SCIENTIFIC REASONING SKILLS

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An increasing number of countries in the world admit the outstanding importance of high-quality teachers. Studies have started to focus on teachers' effectiveness through the examination of the relationship between teaching strategies and student performance. The first aim of our research is to examine whether the strategies favoured by Hungarian teachers are consistent with the international findings; then, we will explore the relationship between the identified strategies and children's scientific reasoning skills at classroom level. We hypothesize a correlation between classroom teachers' teaching strategy and children's performance. Our research consists of two parts: (1) a teachers' questionnaire about teaching and (2) an assessment of students' reasoning skills. The online data collection was carried out in 2015 among 237 classroom teachers and 4010 primary school students in Grade 4. The teachers' questionnaire consists of 30 items; the scientific reasoning test consists of 64 items. The reliability of both assessment instruments *was good (questionnaire: Cronbach's alpha=.81, test: Cronbach's alpha=.85). We have directly linked each teacher to his/her classroom; therefore, we received more accurate results than school level-based studies. In line with international findings, we identified three subscales of teaching strategy by using factor analysis (KMO=.785): teacher-directed, cognitive-activation and active learning strategy. The most commonly used instructional strategy is teacher-directed, which is followed by the cognitive activation and the active learning strategy. Active learning is the only strategy that shows correlation with the scientific reasoning test (r=.22, p<.05), and teachers who have participated in in-service training programmes about teaching science subjects use active learning methods more frequently (r=.18, p<.01). Considering these results, we have to offer more opportunities for teachers to expand and improve their teaching techniques to encourage active learning strategies in the classroom.*

Keywords: teaching methods, primary school, scientific reasoning

THEORETICAL FRAMEWORK

The success of education is influenced by many factors, and one of the key elements is the teacher. The outstanding importance of high-quality teachers is more and more recognised all over the world. Several research projects focus on the study of teachers' knowledge, beliefs and self-efficacy, and an increasing number now focus on teacher's effectiveness through the examination of the relationship between teaching strategies and student performance, e.g. Catalano, Perucchini and Vecchio (2014); Samson, Enderle and Grooms (2013). Due to international student assessments, many background studies started to examine the extent of different effects on student performance. Schroeder, Scott, Tolson, Huang and Lee (2007) looked at the effects of teaching strategies on student achievement in science. They analysed sixty-one studies and identified 8 teaching strategies. The main message of this study is that alternative teaching strategies exerted a positive influence on student achievement when compared with the traditional teaching methods used in the instruction of the control groups.

The direct antecedent of our research is the OECD's 'Teaching Strategies for Instructional Quality' research, which is based on the analysis of the TALIS-PISA link database (OECD, 2016). The OECD linked the PISA 2012 mathematics results to the teaching strategies part of the TALIS questionnaire to gain some insight into teachers' effectiveness in the 8 participating countries. This research identified three main teaching strategies at school level: active learning, cognitive activation and teacher-directed instruction (Table 1). Student discussions, teamwork, cooperation and both peers' and tutor's reflexions play a key role in the use of active learning. The cognitive activation strategy uses instructional methods that create challenges for students engaging their higher order thinking skills to solve the problem. Teacher-directed instruction is clear, simple and easy to follow; requires no complex thinking skills.

Table 1. Teaching strategies among mathematics teachers based on their classroom practices (OECD, 2016. p. 2)

Active learning	Cognitive activation	Teacher-directed instruction
• Consists of promoting the engagement of students in their own learning. • Under this strategy, students' discussions, group work, co-operation, reflection and the necessary support to foster these activities play a central role. • Furthermore, the inclusion and use of information and communication technologies (ICT) in the classroom can help to foster an interactive and individual learning environment.	• Refers to the use of practices capable of challenging students in order to motivate them and stimulate higher-order skills, such as critical thinking, problem solving and decision making. • This strategy not only encourages students to find creative and alternative ways to solve problems, but enables them to communicate their thinking processes and results with their peers and teachers.	• Refers to teaching practices that rely, to a great extent, on a teacher's ability to deliver orderly and clear lessons. • Making explicit the learning goals, providing a summary of previous lessons or asking short, fact-based questions are examples of practices that help to structure lessons.

According to the TALIS-PISA results, students learning through the cognitive-activation strategy achieved significantly better results than others. The teacher-directed strategy is mostly used among lower-preforming students. Thus, the teacher-directed strategies can help students succeed on easier tasks, but they may not be the best strategy in the long run to prepare students for more complex tasks. The study did not find any significant connection between the strategies used and the level of students' engagement. Teachers working at the same school tend to use similar strategies, and the teachers in schools with students from disadvantaged socio-economic background tend to have fewer opportunities to attend further training. This research focuses on mathematics teachers and the mathematics performance of 15-year-old students. For the development of our teachers' questionnaire, we took the TALIS-PISA link data analysis into account, but we also examined younger students, and the students' scientific thinking. Our research is highly relevant because very little data is available about the instructional methods used by Hungarian classroom teachers and their impact on students' scientific knowledge. Most importantly, we have examined one of the main components of scientific knowledge: scientific reasoning skills.

There is a growing need to learn the methods of science along with science content. Scientific reasoning is an important component under the cognitive strand of 21st century skills and is highly emphasized in the new science education standards (Zhou et al., 2016). There is a greater emphasis on general reasoning skills needed for open-ended scientific inquiry (Bybee & Fuchs, 2006). Scientific reasoning can be defined as international knowledge-seeking and coordination of theory and evidence (Kuhn, 2002). This process of knowledge acquisition change encompasses the abilities to generate, test and revise theories and hypotheses, and to reflect on this process (Kuhn & Franklin, 2007; Wilkening & Sodian, 2005; Zimmerman, 2007). Scientific reasoning skills include the ability to systematically explore a problem, formulate and test hypotheses, control and manipulate variables, and evaluate experimental outcomes (Bao et al., 2009; Zimmerman, 2007). Scientific reasoning is important for participation in the knowledge society as an autonomous, critical thinker and is a key part of so-called 21st century skills (Fischer et al., 2014; Osborne, 2013). Traditionally, developmental psychologists argued that scientific reasoning skills emerged only during adolescence (Inhelder & Piaget, 1958). In contrast, in the last 20 years developmental research has found plenty of evidence for the existence of early competencies (Bullock, Sodian, & Koerber, 2009; Zimmerman, 2007). Research findings indicate the appearance of basic experimentation and evidence evaluation skills in preschool and elementary school children.

AIMS

The aim of our study was to twofold. First, we explored the underlying factors of teachers' teaching strategies in 4th grade science class. Secondly, we looked at the effects of the teaching strategy used on students' scientific reasoning performance. In line with the OECD research, we hypothesized that teacher-directed strategies and cognitive activation strategies are used the most by the teachers, while active learning strategies are used less often. We predicted a connection between teaching experience and the strategies used. As the test measured scientific reasoning skills and inquiry skills, we expected students using cognitive activation and active learning strategies to perform better.

METHODS

Sample

The sample of the present study was drawn from the Hungarian Education Longitudinal Program (HELP), in which 4010, 4th grade students of 206 classes of 113 schools participated (Table 2). The sex ratio in the students' sample is balanced.

The teachers' questionnaire was completed by the science teachers working in the participating classes, and all together 237 primary school teachers participated in our research. The average age of teachers in the sample is high; half of the teachers are older than 50 years and have more than 30 years of experience (Table 2). The sample is reasonably typical of Hungarian conditions (Eurostat database, 2017). The average age of Hungarian teachers is high (around 40 years old), most of them are women; there is a shortage of male teachers and science teachers as well. Most of the lower elementary teachers in our sample have a degree from a teacher training college and teach in Grades 3 and 4. Only 5% of our sample has got a university degree. Almost 80% of the teachers participated in in-service teacher training in the past 3 years. Based on the available data, we linked and analysed the achievement data of 2618 students and the teaching strategies of 135 teachers.

Table 2. Characteristics of the teachers and students

Teachers	Students
Number of teachers: 237	Number of students: 4010
Females: 96.2%	Females: 50.5%
Average age: 47.8 years (SD=8.6)	Grade: 4
Qualifications: 93.2% college degree	Number of classes: 206
Average professional experience: 25.0 years (SD=10.5 years)	Number of schools: 113
Further training: 78.4%	

Measurements

To explore teaching strategies, we composed a self-reported questionnaire based on the TALIS items (OECD, 2014). Besides background variables (gender, age, qualifications, professional experience, in-service training) we identified the use of instructional methods using 22 items. 9 of the items were the same as those used in the TALIS study. The questionnaire consists of three subscales with one subscale for each of the three strategies. Six items belonging to the active learning subscale examine the frequency of the students' experiments, short presentations, projects and the out of school social activities during science classes. Nine items of the cognitive activation subscale measure the use of discussions, debate, problem-based assignments, the presentation of the connection between science and everyday life; and seven items of the teacher-directed strategy subscale assess the emphasis teachers put on the transfer of the curriculum, on highlighting the essential elements, on practicing the assignments and on helping students lagging. We used a four-point Likert scale (1 = never, 2 = rarely, 3 = often, 4 = always).

The online Scientific Reasoning test consists of two subtests (Table 3). One of the subtests measures some basic reasoning skills with 29 alternate or multiple-choice items. In order to complete the tasks students had to operate different thinking processes such as conservation; proportional, correlational, probabilistic reasoning and classification skills in science context (Figure 1). These reasoning skills are the general components of thinking, and they play a fundamental role in the acquisition of scientific knowledge.

The inquiry skills subtest consists of 35 items assessing different types of inquiry stages: identifying research questions and hypothesis, designing experiments, interpreting data and drawing conclusions (Figure 2). These skills are important components of scientific knowledge and the knowledge acquisition process.

Table 3. The subtests of the Scientific Reasoning test

Subtest		Number of items	Cronbach's alpha
Reasoning skills	Conservation Proportional reasoning Inductive reasoning Classification	29	.74
Inquiry skills	Identifying research questions Designing experiments Identifying variables Interpreting data Drawing conclusions	35	.77
Total test		64	.85

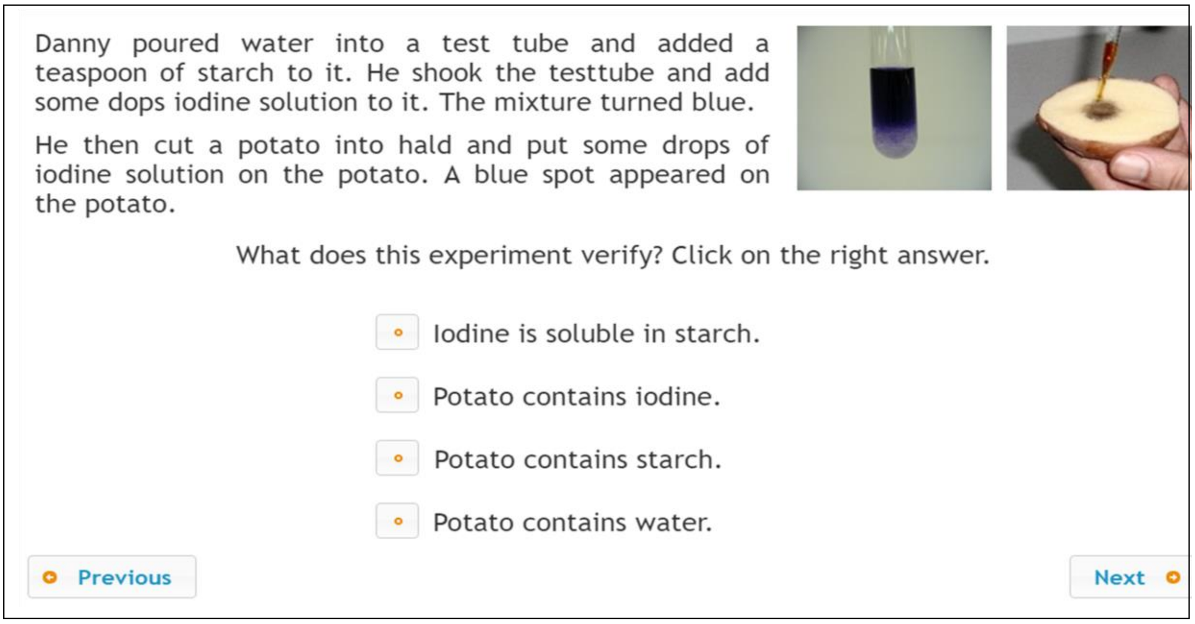

Figure 1. An example of measuring proportional thinking in the Scientific Reasoning test

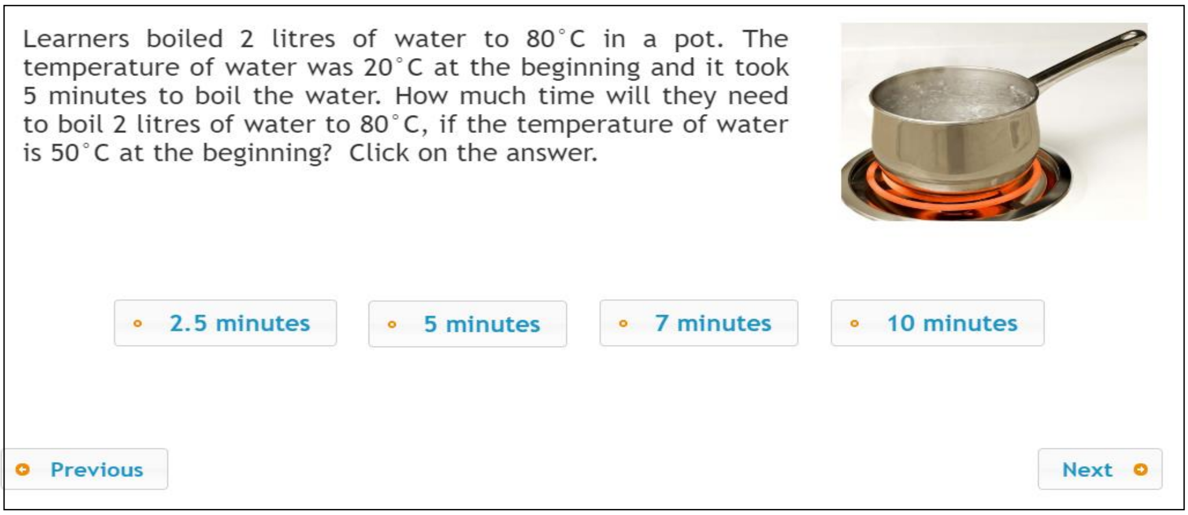

Figure 2. Analysis of the experiment and drawing conclusion – A sample item for measuring the inquiry skills in the Scientific Reasoning test

Data collection was carried out in May 2015. The assessments were carried out in the schools' ICT rooms by means of the eDia (Electronic Diagnostic Assessment) system. Students completed the online tasks by clicking on or moving objects on the screen by dragging-and-dropping. Immediate feedback was given after test completion.

RESULTS

The reliability of the questionnaire was good (Cronbach's alpha=.81). As a result of the exploratory factor analysis (KMO=.785), we identified three subgroups in line with the TALIS-PISA link report (OECD, 2016): active learning, cognitive activation and teacher-directed strategy. During the analysis, we summed the scores of the items belonging to the same subscales. The most commonly used instructional strategy is teacher-directed, which is followed by cognitive activation and the active learning strategy (Table 4).

Table 4. The frequency of teaching strategies uses among teachers (N=237)

Subscales	Mean (%)	SD (%)
Active learning	51.9	9.0
Cognitive activation	73.2	9.1
Teacher-directed strategy	80.2	9.5

The correlation analyses between teaching strategies revealed that the strongest correlation is between the use of active learning and cognitive activation strategy (r=.47, p<.01), while the teacher-directed strategy shows a stronger correlation with the cognitive strategy (r=.31; p<.01) than with the active strategy (r=.14, p<.05).

We found no difference in strategy use based on age or teaching experience. For the background variables, the only correlation is in the case of in-service professional training: those who have participated in in-service training programmes on teaching science subjects, are the ones who use active learning methods most frequently.

The scientific reasoning test proved to be reliable (Cronbach's alpha=.85). The results of the inquiry skills subscale are significantly higher than the reasoning skills measured on scientific content (paired samples statistics t=-20.252 p<0.01). Broken down by gender, girls' performance is higher on both the complete test and on the subtests as well (Table 5).

Table 5. Students' scientific reasoning achievement (N=4010)

Scientific Reasoning Test		Total sample		Boys		Girls	
		Mean (%)	SD (%)	Mean (%)	SD (%)	Mean (%)	SD (%)
Sub-test	Reasoning skills	50.1	15.5	48.9	15.6	51.4	15.4
	Inquiry skills	54.3	15.6	52.3	16.0	56.3	15.1
Total test		52.4	14.1	50.8	14.4	54.1	13.7

To examine the correlations between teaching strategy and science test results, we compared the teachers' total scores on the three subscales to the results of the 4th grade students' who they taught (N=2618). Only the active learning strategy shows a significant correlation with the scientific reasoning test ($r=.22$, $p<.05$) and the inquiry skills subtest. and the inquiry skills subtest ($r=.24$, $p<.05$). Among the examined 22 items, performance is positively correlating with 3 subscales of active learning: 'We make student presentations.' ($r_{reasoning\ skills}=.34$; $r_{inquiry\ skills}=.32$; $r_{total\ test}=.34$ $p<.01$); 'We conduct student experiments according to my instructions.' ($r_{reasoning\ skills}=.25$; $r_{inquiry\ skills}=.25$; $r_{total\ test}=.26$ $p<.01$); 'We visit out of school places (e.g. zoo, museum, nature trail).' ($r_{inquiry\ skills}=.25$; $r_{total\ test}=.21$ $p<.01$). The teacher-directed item of 'I help those, for who the learning material is too difficult.' correlates negatively with the test performance ($r_{reasoning\ skills}= -.23$; $r_{inquiry\ skills}= -.28$; $r_{total\ test}= -.27$ $p<.01$).

DISCUSSION AND CONCLUSIONS

Our data suggest that Hungarian primary teachers in the science lessons prefer frontal methods with teacher-directed processing and practicing of the instructional material. The cognitive activation strategy, in which students are given the opportunity to discuss the issues raised and to get to know the social relevance of the learning material, is used with a similar frequency. The least typical strategy in the classroom is a method relying on students' active participation (e.g. student experiments, project work, presentations, inquiry-based learning). This could be explained by the learning material, which is a large amount and is very much knowledge-oriented already in the early phase of learning, which has an effect on teaching strategies. Teachers concentrate on the transmission of knowledge and to teach the basic terms and relationships, therefore, they have little time for an active student activity, for inquiry, examination and to discuss experiences.

The other factor that influences the differences found on the use of diverse instructional strategies could be teachers' preparedness and their existing methodological knowledge. Our results are in accordance with previous research results (see for example Hódi, B. Németh & Tóth, 2017; Rice, 2010). They show that teaching experience has less influence on the instructional methods used by the teachers, it only plays a role during the initial phase. Our data show that the in-service training programmes have a higher impact on the use of active learning strategies – which are the most effective in the development of scientific reasoning –, than teaching experience has. Our research draws attention to the importance of in-service teacher training, and to the key importance of the integration of modern teaching methods into classroom practice.

We would expect that in the development of scientific thinking both cognitive and active strategies have a demonstrable effect. Our data, however, only confirmed the role of active learning strategies. This can be explained by the nature of the test. The inquiry skills subtest measured such skills, of which development can be promoted by active learning methods, like student observations, examinations, student experiments facilitated by the teacher.

LIMITATIONS

The teachers' questionnaire used self-report. As a next step, we could analyse actual teaching practice through video-analysis on a smaller sample, and it would be necessary to ask the students on the applied teaching and learning methods during science lessons. The examined teaching strategies explain the differences between students' performance to a small extent. To understand the further effects, it would be necessary to reveal students' affective features and socio-cultural background, and other features of the learning environment. Our research focused on the early phase of scientific learning, when according to age characteristics, both the nature of the curriculum and the teaching strategy is different than in the latter phases. Teachers' qualification varies as well. From 1st to 4th grade, mostly teachers with college degree teach science, while from 5th grade – with the beginning of the disciplinary education – subject teachers with scientific qualification participate. Therefore, it would be advisable to extend the research to the upper elementary school and to secondary school as well.

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