How confident are primary school teachers to teach science? A comparative European study

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Abstract

This study aims to explore how European primary school teachers themselves apprehend their ability to teach science to 4th grade students. We have studied how teachers expressed confidence to teach science, different disciplines, topics and specific tasks in science, and explore confidence variation among European countries, male and female teachers, teachers with and without educational specialization in science and experienced and less experienced teachers. The results are based on replies from 4600 4th grade teachers` from 21 European countries in TIMSS 2011. The main results are that there are significant differences among teachers from different countries, and that the teachers generally express a lower confidence in teaching Physical Science compared to Life Science and Earth Science. We discuss what relevance teacher professional confidence and competence may have for primary school science teaching and education of primary school teachers.

Keywords: science; primary school teachers; confidence; education in science

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Introduction

Gardner (1975) stated in his review of students' interest and attitude to science that early primary school teaching is important. Since then many studies have focused on the importance of science teaching in primary school (e.g. Klepaker, Almendingen, and Tveita, 2007; Halim and Meerah, 2002; Harlen, 1986; Smith, 1999) and the role of the teacher preparation (reviewed in Darling-Hammond, 2000). Studies have documented that primary teachers often lack confidence and competence for teaching science (Appleton, 1995; Kennedy, 1998; Loucks-Horsley, Hewson, Love and Stiles, 1998; Palmer, 2001; Riggs and Enochs, 1990; Yates, and Goodrum, 1990), and that this may relate to limited science education given in many initial teacher education programs (Gess-Newsome, 1999; Lawrance, and Palmer, 2003). We want to explore if confidence among primary school teachers relates to their education and experience, and if variation relates to countries and science disciplines. We use the term *teacher professional confidence* (in short: confidence) for what we quantify in two constructs calculated from the responses from the primary school teachers. This implies that teachers are asked to evaluate two competences, their subject content knowledge and their pedagogical content knowledge (Shulman, 1987).

Body

Material and Methods

The data used in this study was obtained from the 2011 Trends in International Mathematics and Science Study (TIMSS 2011), retrieved from the IEA international database. We selected the data from primary school teachers (4th grade) from 21 European countries participating in TIMSS 2011, with a total of over 4600 teachers (Table 3 in Appendices). The primary school teachers filled in a questionnaire giving information of themselves, their classes and their teaching. In two different parts of the questionnaire, the teachers were asked to state their perceived competence to teach science. In one part, they responded to how they felt prepared to teach 20 different science topics; 6 in Life Science, 8 in Physical Science and 6 in Earth Science (Table 1). The response was given in a three-graded scale: Very well prepared (coded 3), somewhat prepared (coded 2) and not well prepared (coded 1). The 20 science topics the teachers responded to are given in Table 2, and the mean value of the science topics is used as construct for teachers' *science topic teaching confidence* (in short STTC). The teachers were also asked to state how confident they were to organize and conduct their science teaching (Table 2). They responded to five different tasks in a three-graded scale: Very confident (coded 3), somewhat confident (coded 2) and not confident (coded 1). The mean value of the five tasks was used as a construct for the teachers' *science teaching conduction confidence* (in short STCC). To remove relative differences in confidence levels between countries, standard scores were computed for the constructs for each country, where construct means equal zero and standard deviations equal one. In this way, we can compare patterns of variation between different topics (topic profiles) and teachers with and without specialization in science and to relate confidence to teaching experience. The teachers were asked to specify if they had a specialization or a major in science. A positive answer to one of these questions was the criteria for teachers with science education (specialization). The teachers did not specify if their education in science was in integrated science or a specialization in Life, Physical or Earth Sciences.

Table 1: The topics in Life Science, Physical Science and Earth Science the teachers responded to how well they felt prepared to teach (used for the construct STTC).

It. No.	Topic
	Life Science
L1	Major body structures and their functions in humans and other organisms (plants and animals)
L2	Life cycles and reproduction in plants and animals
L3	Physical features, behavior, and survival of organisms in different environments
L4	Relations in a living community (e.g., simple food chains, predator-prey relationships)
L5	Changes in environments (effects of human activity, pollution and its prevention)
L6	Human health (e.g., transmission/prevention of communicable diseases, signs of health/illness, diet, exercise)
	Physical Science
P7	States of matter (solids, liquids, gases) and differences in their physical properties (shape, volume) including changes in state of matter by heating and cooling (melting, freezing, boiling, evaporating, condensation)
P8	Classification of objects/materials based on physical properties (e.g., weight/mass, volume, , magnetic attraction)
P9	Forming and separating mixtures
P10	Familiar changes in materials (e.g., decaying, burning, rusting, cooking)
P11	Common energy sources/forms and their practical uses (e.g., , sun, electricity, , water, wind)
P12	Light (e.g., sources and behavior)
P13	Electrical circuits and properties of magnets
P14	Forces that cause objects to move (e.g., gravity, push/pull forces)
	Earth science
E15	Water on earth (locations, types, and movement)
E16	Common features of Earth's landscape (e.g., mountains, plains, rivers, deserts) and relationship to human use (e.g., farming, irrigation, land development)
E17	Weather conditions from day to day or over the seasons
E18	Fossils of animals and plants (age, location, formation)
E19	Earth's solar system (planets, Sun, moon)
E20	Day, night, and shadows due to Earth's rotation and its relationship to the Sun

Table 2: The five teaching tasks the teachers were asked to state how confident they felt to conduct (used for the construct STCC).

Task number	Teaching task: How confident do you feel to:
1	Answer students' questions about science
2	Explain science concepts or principles by doing science experiments
3	Provide challenging tasks for capable students
4	Adapt my teaching to engage students' interest
5	Help students appreciate the value of learning science

There are some challenges in using data gathered for other purposes in new settings. We cannot influence on how samples are made or what questions that is presented and how they are formulated. One challenge is that the topics and teaching tasks we use for our confidence constructs (STTC and STCC) were not designed for this specific purpose. For example, we would prefer a smoother Likert scale than a 3 point scale for the purpose. Also, the 20 topics forming the STTC construct and the 5 tasks forming the STCC construct could have been more specifically chosen for the purpose. However, the 20 topics were constructed to cover science curricula in the participating countries (Mullis, Martin, Ruddock, O'Sullivan, and Preuschoff, 2012) and we consider the constructs as sufficiently robust and valid to provide informative comparisons.

Variables based on ranking categories often fail to meet the assumption of normal distribution, and Kolmogoro-Smirnov tests showed that this is the case for the confidence variables in this study. Therefore, non-parametric tests are used. Mann-Whitney U-test is used for testing equality of distributions between two groups and Kruskal-Wallis test is used for testing equality of distribution when more than two groups are compared. Bivariate correlations are computed by Spearman Rank Correlation. The reliability of all constructs was tested by calculating Chronbach's alfa. All alfa values were above 0.84, showing good construct reliability. All statistical analyses have been performed using IBM SPSS 19.

Results and discussion

When the primary school teachers from the 21 European countries report how well they felt prepared to teach science topics; 60 percent of all teachers answered ”very well prepared”, 34 percent answered “somewhat prepared”, and 6 percent answered “not well prepared”. But the distribution varies between the countries, disciplines and topics. The distributions of the science topic teaching confidence construct (STTC) for each country is given in Figure 1, and we find a significant variation among the countries (Kruskal Wallis test: $\chi^2_{20} = 857$, $p<0.001$). Highest STTC scores are found in Romania (2.85), Portugal (2.75), England (2.73), Georgia (2.73) and Slovak Republic (2.72). The lowest STTC scores are found in in Germany (2.31), Netherlands (2.31), Norway (2.24) and Italy (2.24). Comparing self-confidence in teaching Life Science, Physical Science and Earth Science, we see that European teachers express higher self-confidence in Life Science (mean score=2.66) and Earth Science (mean score=2.60) compared to Physical Science (mean score=2.44). This pattern is consistent in the majority of the countries (Table 3 in Appendices). The only exceptions are England, North Ireland and Slovenia where Physical science has a higher score than Earth Science, and in Romania and Ireland where the three discipline scores are fairly equal.

The responses to how confident the teachers feel to conduct their science teaching also show a high confidence in general. Combining all answers provide 57 percent “very competent”, 39 percent “somewhat competent” and 4 percent “not competent”. Comparing the five teaching tasks (Table 2), we see that the teachers express least confidence in “Explain science concepts or principles by doing science experiments” and “Provide challenging tasks for capable students” (Table 3 in Appendices). Combining the five science teaching conduction tasks into the construct (STCC), show that the mean value of this construct (2.54) equals the mean of STTC. Also, here we see significant differences between countries (Kruskal Wallis test: $\chi^2_{20} = 924$, $p<0.001$). Highest STCC scores are in Romania (2.92), Croatia (2.79), Georgia (2.74) and Serbia (2.73). Lowest STCC scores are in Germany (2.26), Italy (2.28) and Netherlands (2.30) (Figure 1 and Table 3 in Appendices). The correlation between the STTC and STCC constructs is 0.63 (Spearman Rank Correlation), showing a significant ($p<0.001$) co-variation between the two constructs of primary science teachers confidence. The countries where the two confidence constructs differ most are Ireland (in favor of STTC) and Croatia, Romania and Norway (in favor of STCC).

The teachers in the study group are experienced teachers with a mean of 17 years of teaching experience. A weak, but positive and significant correlation was found between teaching experience and the two confidence constructs (Spearman rank correlation: STTC: $r = 0.08$, $p<0.001$, STCC: $r = 0.10$, $p<0.001$). But studying the correlations within each country reveals that only a few countries contribute to the positive correlations. For STTC we find positive and significant correlations only in Germany (r=0.30), England (r=0.22) and Denmark (r=0.19) and for STCC in England (r=0.20), Hungary (r=0.13) and Poland (r=0.13).

Three of four teachers report that they have no specialization in science in their education. The frequency of teachers with specialization in science varies considerably between the countries. Georgia (72%), Germany (67%), and Sweden (64%) are in the top end, while Serbia (3%), Slovenia (5%), Ireland (9%) and Netherlands (9%) are the countries with the lowest report of science specialization. In all countries combined, we find small, but significant confidence differences for both STTC and STCC. However, as for gender, differences between countries due to other factors may obscure the results. Therefore, we use the standardized constructs for the comparison. For the standardized STTC means we see a clear difference (0.25 standard deviations) in favor of teachers with specialization (Mann-Whitney: $p<0.001$). Looking at the science disciplines, we see that the confidence differences are largest for Physical Science (0.34 standard deviations) and least for Life Science (0.21 standard deviations). Also for standardized STCC means we see a clear (0.31 standard deviations) and significant difference between teachers with and without specialization (Mann-Whitney: $p<0.001$). We see significant differences in favor of teachers with specialization in all five tasks.

To explore if confidence patterns are shared by different countries, we use standardized values for each topic (mean = 0 and standard deviation = 1 in each country). By this, differences in self-confidence levels between the countries were eliminated, and the pattern of variation between the topics can be compared. A profile of the variation between the 20 topics is given in Figure 2. This profile show two things; self-confidence between science topics differs much, and it is a large degree of consistency in the variation pattern between different countries.

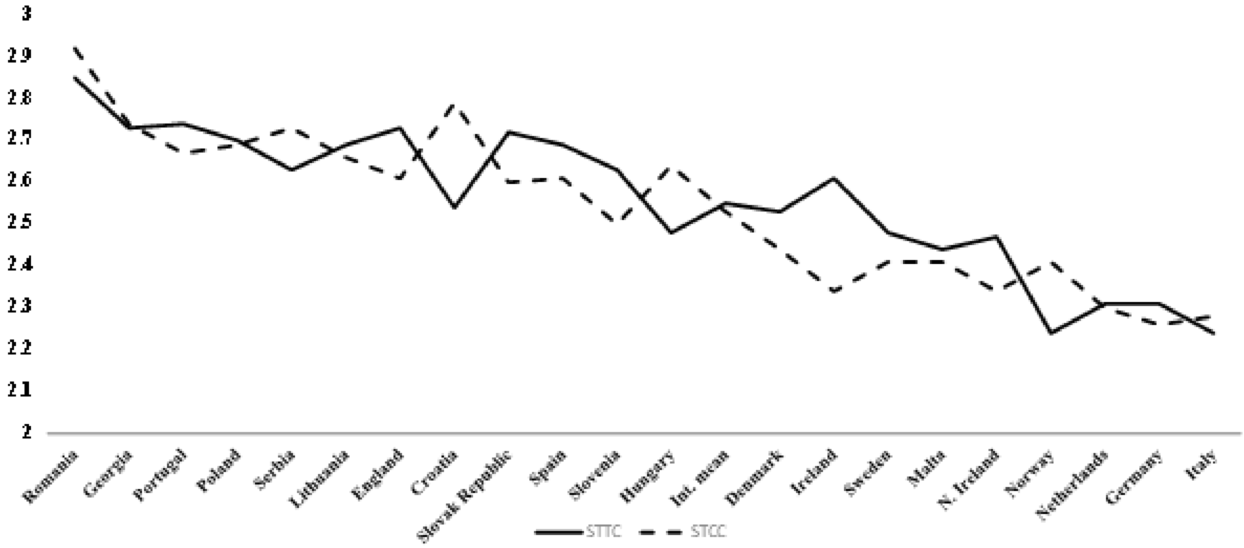


Figure 1. The mean confidence scores for the European countries for the STTC and STCC constructs. The countries are ranked according the mean value of the two confidence constructs.

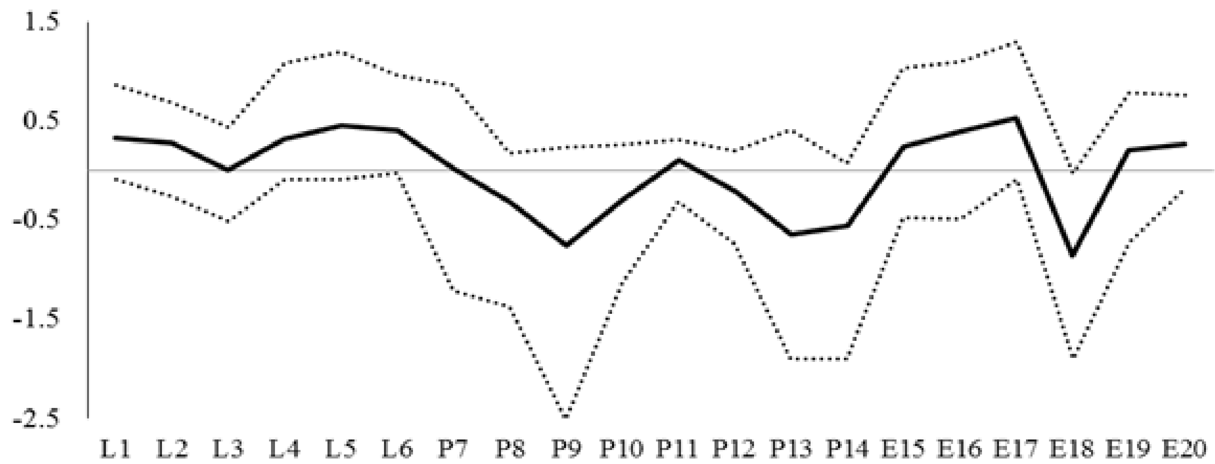
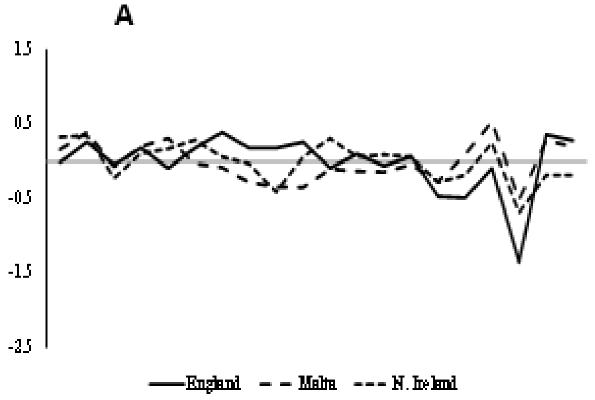
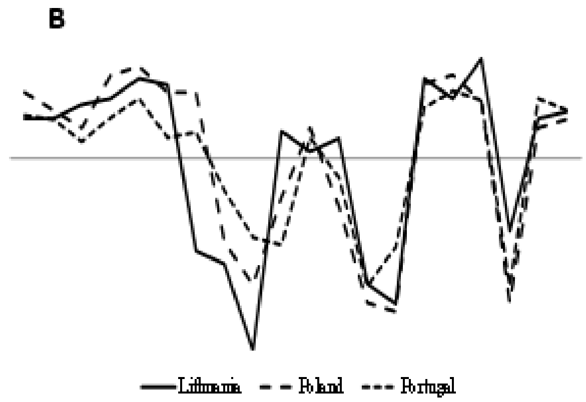


Figure 2. Standardized confidence profile pooled for all 21 countries. Positive values represent topics where teachers' confidence is above average, negative values are topics below average. The dotted lines are minimum and maximum values for countries. The topic numbers refer to Table1.

But some variation in profile does exist. England, Northern Ireland and Malta are characterized by profiles with small amplitudes, meaning small differences in self-confidence between topics (Figure 3A), while Lithuania, Poland and Portugal are in the other end having profiles with large amplitudes (Figure 3B). The rest of the countries are more in direction of large amplitudes than low amplitudes.





We have also related self-confidence profiles to teacher specialization, but we find no significant difference in confidence profile among teachers with and without science specialization.

We will now look into some of the topics where the European primary school teachers express the lowest self-confidence. In Life Science, all topics have a mean self-confidence score at or above the overall mean (Figure 2). The one with the lowest score are L3: “Physical features, behavior, and survival of organisms living in different environments”.

For Physical Science, only one of the eight topics is above the overall mean of self-confidence score. The topic P9: “Forming and separating mixtures” have the lowest score among the Physical Science topics. For eight of the countries this topic is more than one standard deviation below the overall mean. Especially Lithuania and Poland are low for this topic relative to the others, while Slovenia and England and Slovenia are the only countries with positive values. Two other Physical Science topics have low scores relative to other topics; P13: “Electric circuits and properties of magnets” and P14: “Forces that cause objects to move (e.g., gravity, push/pull forces)”. Here, respectively seven and five countries are below one standard deviation from the overall mean, and Lithuania, Poland and Portugal stand out as the countries that have the lowest relative score for these topics. England, Northern Ireland and Malta, on the other hand, are the only countries where these topics do not deviate from the overall mean. All but one topic in Earth Science are over the overall mean. The one below: E18: “Fossils of animals and plants (age, location, formation)” is clearly standing out from the rest of the Earth Science topics, and is the lowest relative to all other topics. The lowest scores are found in Poland and Portugal, while Norway, Georgia and Italy are the only countries where the topic is not deviating from the overall mean.

What is the significance of this variation in teachers’ professional confidence? First, it is important to state that high confidence cannot directly be interpreted as high teacher competence; even though it is likely that a teacher’s science knowledge, teaching competence and confidence are linked (Summers and Kruger, 1992; Harlen and Holroyd, 1997; Shallcross, Spink, Stephenson and Warwick, 2002). We see in this European study that only one of four primary school teachers who teach science has an educational specialization in science. And we see that teachers with education in science express higher confidence. This holds both for how they comprehend their ability to teach different science topics and to solve teaching tasks. However, emphasis on educating science teachers seems not to be an important predictor of variation in confidence between countries; no relation is found between confidence and proportion of science educated teachers among different countries. This indicates that there are other important factors influencing confidence that varies among countries, and one may be differences in the teacher education programs in different countries.

Teacher efficacy has been found to relate to teaching experience (Rubeck and Enochs, 1991; Ross, Cousins and Gadalle, 1996; Wolters and Daugherty, 2007), so it is reasonable to expect that experienced teachers have developed higher confidence. To our surprise, the relations between years of teaching experience and confidence were weak and none existent in most countries. Only in a few countries (England, Germany), we see a consistent increase in confidence with teaching experience. However, Klassen and Chiu (2010) states that the relationship between teacher efficacy and teacher experience may be more complex than previously believed. They found that all confidence factors in the efficacy constructs first increased with years of experience, then showed a gradual decline, which they related to a decline in motivation and disengagement. How lack of confidence in science among primary school teachers can affect their teaching was described by Harlen and Holroyd (1997). They identified a set of coping strategies teachers adopted to compensate for low confidence and low understanding on specific subjects: shifting weight from low-confidence to higher confidence aspects, heavy reliance on pre-made kits and texts with clear step-by-step instructions, emphasizing expository teaching downplaying questioning and discussion and avoiding all but the simplest practical work. They found that confidence influenced teaching in general, but especially in specific subjects.

We found that there was a consistent pattern in the differences in teachers' confidence for teaching different science disciplines. We see that in the majority of countries, teachers express a pronounced lower confidence in teaching Physical Science compared to Life Science and Earth Science. It is reasonable to assume that this is rooted in a lower perceived competence in Physical Science among primary school teachers in general (Lawrance, 1986; Harlen and Holroyd 1997; Murphy, Neil and Beggs, 2007). The question is then, what causes this difference? The teachers with no educational specialization in science express a larger drop in self-confidence in Physical Science than teachers with a specialization, indicating that teacher education might play a role. Enochs, Scharmann, and Riggs (1995) found significant correlations among science teaching self-efficacy and the number of science courses taken, instructional practice, and perceived teaching effectiveness. We have no information of the weight of the different disciplines in the respective teacher educations, and can therefore not say if less emphasis on Physical Science in teacher education programs can account for the difference in confidence. But we see that the discipline difference exists among teachers both with and without specialization, indicating that a generally lower confidence in Physical Science cannot only be explained by the structure of teacher education. We know that students generally perform lower in Physical Science from international studies like TIMSS and PISA (Martin, Mullis and Foy, 2008; OECD, 2010), and also express a more negative attitude to it (Bricheno, Johnston and Sears, 2001; Gardner, 1985; Kelly, 1987). It is possible that reduced knowledge and attitude at school is linked to teacher competence in a negative feedback; teacher students enter their teacher study with a lower competence in Physical Science, which is not fully compensated (taking specialization) or not compensated at all (no specialization). Starting their work in school, their Physical Science teaching will be of lower quality, which result in students with lower competence (Tobin and Fraser, 1988), and when these students start their teacher study their competence level have dropped further. It is interesting to see that the concern of students lacking interest and confidence in Physical Science when they start their primary school teacher education is also raised in England (Shallcross and Spink, 2000) and Slovenia (Devetak Glažar, Vogrinc, and Juriševič, 2009), two of the countries where confidence in Physical Science differ least from the other disciplines. But in a comparative study between primary school teacher students from Finland and England, Johnston and Ahtee (2006) found that English teacher students entered their teacher study with less negative attitude to physics than the students from Finland, indicating a development of a more positive view on Physical Science among English students. Finland participated in TIMSS 2011, but unfortunately for this study, the primary school teachers in Finland did not respond to the teacher questionnaire.

Another consistent pattern we observe is the confidence profile produced from the 20 different topics the teachers have responded to. We expected that different countries with different curricula and different tradition and culture for what parts and topics in science they emphasize, would differ in the way teachers express their readiness for teaching different topics. But what we see is that there exists a general pattern which is less influenced by nationality of the teachers. The same profile is observed regardless of the teacher having specialization in science or not, showing that this is not directly related to what might have the focus in teacher education. Shallcross, Spink, Stephenson and Warwick, (2002), studying English primary school teacher students found that they lacked confidence in areas not covered in their science courses, but it does not seem likely that the same "holes" exist in primary school teacher education throughout Europe. It is interesting to observe that the three countries with least confidence variation among topics, England, Northern Ireland and Malta, all have a British educational tradition.

An important question emerges: To what extent is the confidence the teachers have in their own ability to give high quality teaching an indicator of student learning outcome? We see that the teachers from different European countries perceive their ability to deliver good teaching in science differently. Can this be interpreted as students from Norway and Italy (lowest confidence scores) receive lower quality science education than students from Romania (highest confidence score)? Looking at how the students performed in TIMSS2011 (Martin, Mullis, Foy, and Stanco, 2012), we see no relation between teacher confidence and student performance at a national level. We therefore advise to be careful to conclude that there is a simple relation between teacher competence and confidence. Even if teachers' competence probably is a factor contributing to the professional confidence, direct comparisons between different countries and school system are difficult for several reasons. One of these is that the expectation the teachers meet can be different in different countries. If a teacher in one country feel that much is expected from her, for instance through the national curriculum, she can express a lower confidence than she would have done if she was teaching in another country were the expectations were lower. Further, the teachers compare their skills to fellow teachers. In a country where the general competence level is high, teachers can express lower confidence when they compare themselves with colleagues with high competence. Finally, the students will also influence how teachers evaluate their work; both high skill students demanding much and low performing students contribute to reduced confidence of the teacher.

Conclusion

What consequences should these findings have for education of primary school teachers? First, we see that having science specialization matters; increased emphasis on science in primary school teacher education will result in more confident teachers. Second, the need for strengthening the teachers' competence in Physical Science is evident in almost all countries. Finally, the teachers' confidence also varies between topics within the science disciplines, and there is a pattern here that is consistent between countries. The root of this pattern is probably not within teacher education only, but may indicate areas where more effort should be put in to make these "holes" in science teachers' competence shallower.

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