STEM in Elementary Teacher Training in Austria

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Abstract: Knowledge and skills from STEM subjects are becoming increasingly important. It is therefore important that these elements be implied in the curriculum of all educational institutions, starting already in elementary education. For this purpose, the training of elementary teachers in this field is very important and indispensable. In Austria, STEM topics are included in the curriculum of the vocational secondary school at the Educational Institute for Elementary Teachers. To find out about the actual implementation and impact of their STEM training, elementary teachers were asked to what extent they had become acquainted with the contents of STEM subjects in their teachers training, also with regard to their transfer into practice. The results show that the elementary teachers have received hardly any practical and theoretical information about the teaching of STEM content in their training. Moreover, without additional training, most of the elementary teachers do not feel prepared to teach the required STEM contents defined in curricula for elementary education in their daily work.

1 INTRODUCTION

In infants and toddlers 700 new neural connections are created every second. This rapid brain development, coupled with strong natural curiosity and drive towards understanding the surroundings, presents ideal conditions to present scientific inquiry to children (Buchter et al., 2017). Moreover, research shows that the early exposure to STEM (Science, Technology, Engineering, and Mathematics) related activities supports children's long term development and achievements withing the field: Meaningful experiences with scientific phenomena by young children have been found to increase self-belief in own abilities to understand scientific subject matters and foster greater interest in science (Patrick et al., 2009). Such experiences can also create an appreciation for the role and influence science have on our lives (Fleer et al., 2006). Consequently, children's earliest experiences with science, technology, engineering, and mathematics might subsidize future engagement and success in these fields (Hassan et al., 2019).

Teachers play a key role in fostering children's STEM inquiry, as they can not only provide a physical learning environment, but help to provide context, ask questions, connect previous knowledge to preset experiences and provide language to articulate new concepts (Buchter et al., 2017). Despite this, international research shows that STEM related activities in early childhood classrooms are rare. Science instructions are none frequent and teachers do not spend significant amounts of time on science-related subjects in the classroom (Lück, 2018; Nayfeld et al., 2011; Tu, 2006). Currently, their emphasis is on language and literacy development, with relatively little math in preschool. It has been found that in an ordinary preschool, as little as 59 seconds of a 360-minute day (less than 0.3 percent of the students' time) would be spent on math, and that introductions to science and engineering were rarely part of the curriculum (Farran et al., 2007). Moreover, preschool teachers are poorly trained to support STEM learning (Clements et al., 2013). It is critical that early childhood professionals are highly qualified and competent to support young children's scientific inquiry, as the developmental sensitivity and natural curiosity at this age must be utilized to provide a sound foundation for future engagements in the field of STEM (Clements and Sarama, 2020; Worth, 2010).

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2 TRAINING FOR ELEMENTARY TEACHERS IN AUSTRIA

In an international comparison, Austria is one of the top performers in the field of vocational education. Nearly 76% of graduates from an upper secondary school earn a vocational degree (Federal Ministry of Education, Science and Research, 2021). The OECD average is 38.4%.

One such school with a vocational degree is the "Educational Institute for Elementary Pedagogy", which aims to train elementary teachers. This school can be completed in 2 different ways: in the form of a 2-year technical school with diploma, but with the prerequisite of a maturity examination, university entrance qualification, or vocational maturity examination or a 5-year vocational secondary school with diploma and Matura. In Austria, the Matura is equivalent to a school-leaving qualification from a secondary school with an associated higher education entrance qualification and entitlement to attend a college or university. There are some providers who offer bachelor studies in the field of elementary education. However, compared to other countries, Austria is one of the few countries where the necessary training for staff in elementary education is below the bachelor's level (European Education and Culture Executive Agency and Eurydice, 2019).

2.1 Secondary School Education

The curriculum of the 5-year vocational secondary school with Matura and diploma is divided into 10 semester with a total of of at least 168 teaching hours per week. In addition to general education, these also include the subjects for vocational training for the profession of kindergarten teacher in elementary educational institutions. STEM subjects account for 28 hours per week (16.6% of the total number of hours per week) and are divided as follows: Applied Mathematics, Applied Natural Sciences, Biology and Ecology, Chemistry, Fundamentals of Computer Science and Media, and Physics (Federal Ministry of Education, Science and Research, 2016). The subject Applied Natural Sciences was added to the curriculum in 2016. Before this change in the curriculum, there was no comparable school subject.

As can be seen in Table 1, with the exception of Fundamentals of Computer Science and Media, didactic content is anchored in the curriculum of all subjects. Applied Mathematics accounts for the most teaching hours (10 out of 28 hours per week).

The learning fields of number, space and form, patterns and sequences, sorting and classifying, time and frequency and coincidence are developed in the school subject of Applied Mathematics, divided over five years, with a view to transfer to the pedagogical occupational field. In the school subject Physics in 2 years on the one hand the naming of physical phenomena and on the other hand accident prevention, electric circuit, magnetism. In Chemistry, the curriculum in the second and third year includes experiments and related safety aspects as well as food labeling, food ingredients. In the subject of Biology and Ecology, nature observations, hygiene measures and dealing with children with special needs are part of the curriculum in apprenticeship years one to three. In terms of content, the subject of Applied Natural Sciences in the fourth year of teaching, in that Biology, Chemistry and Physics have already been completed in terms of content, takes up the following natural science topics in the curriculum: Sustainability, ecological footprint, energy, electric current, forces, animate and inanimate nature, technology and inventors, water, elements, soil, forest, time, measurement, weather, sounds and noises, light, sky, bionics, swimming-sinking, floating-flying. The focus is on using technical language appropriate to the age group, formulating research questions, planning and implementing experiments and series of experiments, and explaining scientific relationships in a way that is appropriate to the target group. As a further point, the importance of scientific education for the child is reflected (Federal Ministry of Education, Science and Research, 2016).

It must be mentioned in this context that the teachers employed in "Educational Institute for Elementary Pedagogy" are trained in teacher education in the field of secondary education as well as school subject-specific content, but there is no requirement for experience or studies in elementary education.

2.2 Technical School Education

In the 2-year training in the form of the college prospective elementary teachers are taught 143 hours per week, divided into 4 semesters. The subjects are related to pedagogical practice and the associated subject areas. Looking at the STEM content, there are no specifications in the curriculum. Only the topic of media education is addressed. In a school autonomous extension area - nature and technology, which can be freely selected by the training institution, the following contents are anchored in the curriculum: scientific topics and information, scientific methods, dealing with children's questions, experiments, job-related technical literature, recordings, securing results, mobility and sustainability, colors -

Table 1: Overview about the STEM subjects in the curriculum of the 5-year vocational secondary school.

Subject	Semester	Didactic Topics
Applied Mathematics (10 teaching hours)	1+2	Learning field "Numbers"
	4	Learning field "Space and shape"
	6	Learning field "Patterns and sequences" and "Sorting and classifying"
	8	Learning field "Time"
	9+10	Learning field "Frequency and coincidence"
Applied Natural Sciences (3 teaching hours)	7+8	Sustainability, Ecological footprint, Energy, Electric current, Forces, Inanimate and animate nature, Technology and inventors, Water, Elements, Soil, Forest, Time, Measuring, Weather, Sounds and noises, Light, Sky, Bionics, Swimming-Sinking, Floating-Flying
Biology and Ecology (6 teaching hours)	1+2	Hygiene measures in everyday situations
	4	Nature observations
	6	Dealing with people with special needs
Chemistry (3 teaching hours)	4	Experiments and safety aspects of experiments
	4	Food labeling and food ingredients
Fundamentals of Computer Science and Media (2 teaching hours)	1-4	*no didactic contents in the curriculum*
Physics (3 teaching hours)	4	Name physical phenomena
	6	Accident prevention, electric circuit, magnetism

color mixing - optics, basic experiences with duration, temporal sequence, rhythms, seriality, patterns, structures (Federal Ministry of Education, Science and Research, 2016).

3 METHODOLOGY

With regard to the actual implementation of the curricula in the training of elementary school teachers, questionnaires were created and trained elementary school teachers were asked what content they actually learned in the course of their training. The questionnaires in form of a internet-mediated questionnaire were sent to two different groups. On the one hand to individuals, in order to ensure a deliberate cross-section of different federal states in Austria, years of service and public/private institutions, and on the other hand shared via an internet platform for exchange between kindergarten teachers. The decision to choose a questionnaire came from the fact that a large number of questionnaires should ensure the diversity of elementary teachers with different training institutions, different years of graduation, and thus different teachers at the training institutions. This is to ensure that individual teachers in the training centers do not distort the final result. The questionnaire consisted of two parts. The first part of the questions was with the help of a 4-part answer scale to determine how intensively the didactic topics of the teaching contents in Applied Mathematics, Biology and Ecology, Chemistry, and Physics listed in the curriculum were really dealt with in the training (1- not dealt with at all; 4- discussed in detail and explained with practical examples). The question did not contain the subject Applied Natural Sciences, because of the introduction of Applied Natural Sciences in the curriculum in 2016 resulting in the fact that the elementary teachers participating in this study did not have this subject in their training. All questions in this part refer to the curriculum content of all subjects with STEM content in secondary education for prospective elementary school teachers The second part of the questionnaire relates to the implementation in practice and the question of how far the elementary teachers feel prepared to implement the STEM content in kindergarten practice. There were four possible answers (1- I feel prepared in this area; 2- thanks to further training I feel prepared; 3- I would have to read up on it first; 4- I can't do anything with it). In the questioning all didactic topics in the STEM subjects (Applied Mathematics, Applied Natural Sciences, Biology and Ecology, Chemistry, Fundamentals of Computer Sci-

ence and Media, Physics) from the curriculum were included. The data collection method was chosen to survey a large number of educators and to obtain open and honest responses through anonymity. The standardized questions made it possible to systematically record and compare the answers. It was mandatory to answer all questions to complete the survey. Due to the lack of proper STEM training in the technical school education, only the 111 respondents with the secondary school education were analyzed.

4 RESULTS

4.1 Experienced Intensity of Taught Topics

The first part of the questionnaire determines how intensively the teaching contents listed in the curriculum were really dealt with in the training. The results show that all of the topics were discussed in detail and explained with practical examples, but only for 3.60%-25.23% of the participants.

In sum, the answer “discussed in detail and explained with practical examples”, representing the answer for the highest intensity of curriculum coverage, was given 198 times (11.89%) by 63 different participants (56.76%), the answer representing the second most intensive coverage was given 328 times (19.70%) by 95 different participants (85.59%), the answer representing the second least intensive coverage was given 492 times (29.55%) by 106 different participants (95.50%) and the answer “not dealt with at all” representing the answer for the least intensive coverage 647 times (38.86%) by 98 different participants (88.29%). The distribution of given answers can be seen in Figure 1.

When looking more into the depth, the topic that was most discussed in detail and explained with practical examples was “Experiments and safety aspects of experiments” (n=28) followed by “Nature observations” (n=24) , “name physical phenomena” (n=19) , “Accident prevention, electric circuit, magnetism” (n=18) , “Learning field Frequency and coincidence” (n=16) , “Learning field Patterns and sequences and Sorting and classifying” (n=14) , “Hygiene measures in everyday situations” (n=13) , “Explain scientific relationships in a way that is appropriate for the target group, transfer the acquired practical skills and knowledge to the professional field, reflect on the importance of science education for the child” (n=11) and “explain scientific relationships in a way that is appropriate for the target group, transfer the acquired practical skills and knowledge to the professional field, reflect on the importance of science education for the child” (n=11) , “Dealing with people with special needs” (n=9) and “Learning field Patterns and sequences and Sorting and classifying” (n=9) , “Learning field ”Numbers”” (n=8) and “Use technical language appropriate to age, formulate research questions, plan experiments or series of experiments and implement experimental designs.” (n=8) , “Learning field ”time”” (n=6) , and “Food labeling and food ingredients” (n=4). The topic that was most mentioned as “not dealt with at all” was “Food labeling and food ingredients” (n=67) followed by “Dealing with people with special needs” (n=55) , “Use technical language appropriate to age, formulate research questions, plan experiments or series of experiments and implement experimental designs.” (n=54) , “Explain scientific relationships in a way that is appropriate for the target group, transfer the acquired practical skills and knowledge to the professional field, reflect on the importance of science education for the child” (n=51) and “Learning field Time” (n=51) , “Hygiene measures in everyday situations” (n=48) and “Learning field Frequency and coincidence” (n=48) and “explain scientific relationships in a way that is appropriate for the target group, transfer the acquired practical skills and knowledge to the professional field, reflect on the importance of science education for the child” (n=48) , “ learning field Sorting and classifying” (n=45) , “Learning field Numbers” (n=44) , “Learning field Patterns and sequences” (n=37) , “name physical phenomena” (n=27) , “Nature observations” (n=25) and “Accident prevention, electric

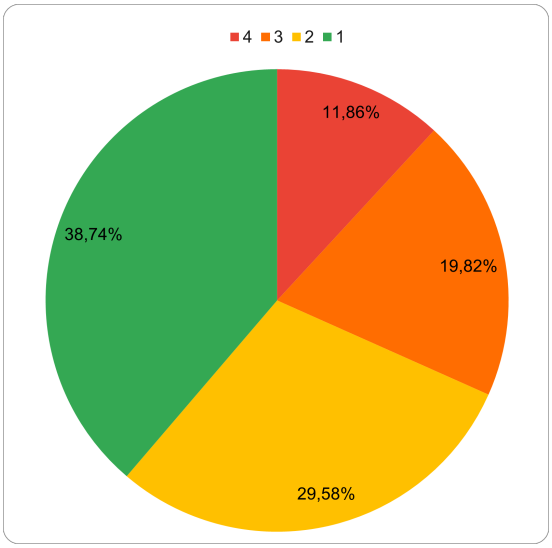

Figure 1: The distribution of given answers to all questions in part 1 how intensively the topics were taught reaching from 1 (“not dealt with it at all”) to 4 (“discussed in detail and explained with practical examples”) by all participants.

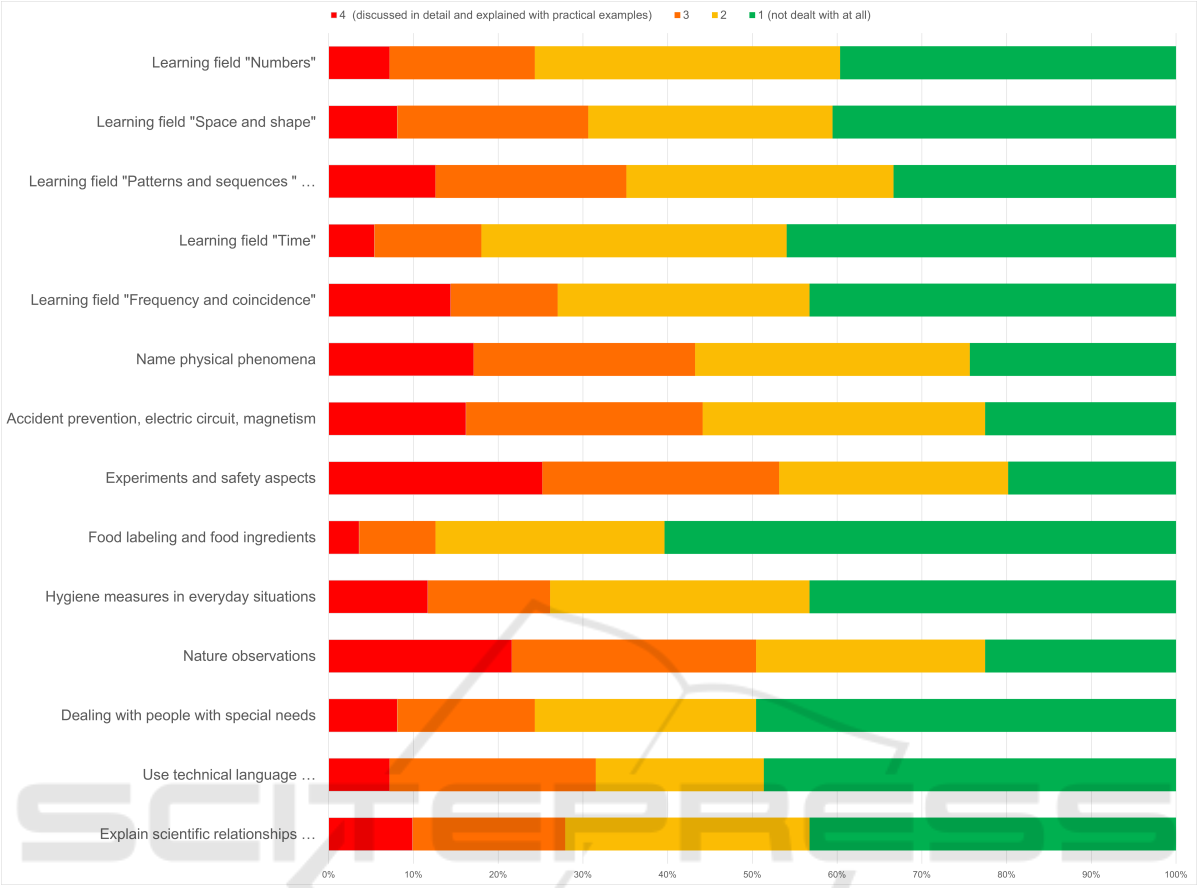

Figure 2: Overview about the intensity of taught topics at the secondary school education for prospective elementary teachers.

circuit, magnetism" (n=25) , and "Experiments and safety aspects of experiments" (n=22). An overview of these results can be seen in Figure 2.

Sixty-three participants answered at least once that the intensity of learning a topic was "discussed in detail and explained with practical examples" (56.76%) resulting in 48 participants who did not answer this for any of the topics (43.24%). One participant answered for all the topics that she/he/* did not deal with them at all.

4.2 Teachers' Self Confidence in STEM Implementation

The third part of the questionnaire relates to the implementation in practice and the question of how far the elementary teachers feel prepared to implement the STEM content in kindergarten practice. The results show that most of the teachers are prepared (56,15%), however, without additional training only 38.54% of the kindergarten teachers feel prepared for the STEM content in practice. And also with additional training, there are still 43.85% kindergarten teachers who do not feel prepared for STEM topics in kindergarten. The distribution of given answers can be seen in Figure 3.

When looking more into the details about the contents in teacher training, the teachers feel the most prepared for the topic "Weather" (n=77), followed by "Forest" (n=71) and "Sounds and noises" (n=71), "Nature Observations" (n=66), "Water" (n=64), "Learning field Sorting and classifying" (n=61), "Swimming-Sinking" (n=60), "Learning field Patterns and sequences" (n=58), "Dealing with people with special needs" (n=55), "Measure" (n=54), "Hygiene measures in everyday situations" (n=53), "Learning field Numbers" (n=51) and "Sustainability, ecological footprint" (n=51), "Elements" (n=48), "Light" (n=44) and "Floating-Flying" (n=44), "Learning field Space and shape" (n=44), "Time" (n=42), "Soil" (n=41), "Learning field Time" (n=36), "Inanimate and animate nature" (n=35) and "Sky" (n=35), "Experiments and safety aspects of experiments" (n=28), "Technology and inventors" (n=22) and "Physical phenomena" (n=22), "Energy, electric current" (n=19), "Forces" (n=18), "Learning field

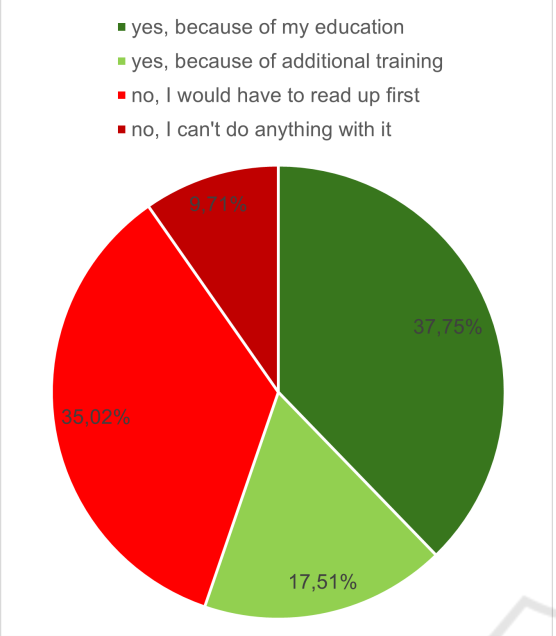

Figure 3: The distribution of given answers to all questions in part 2 how far the elementary teachers feel prepared to implement the STEM content in kindergarten practice.

Frequency and coincidence" (n=17), "Food labeling and food ingredients" (n=16), "Accident prevention, electric circuit, magnetism" (n=15). The topic were the teachers answered "I can't do anything with it" the most often was "Bionics" (n=40), followed by "Forces" (n=25), "Technology and inventors" (n=21), "Energy, electric current" (n=19), "Learning field Frequency and coincidence" (n=17), "Name physical phenomena" (n=16) and "Food labeling and food ingredients" (n=16), "Experiments and safety aspects of experiments" (n=15), "Accident prevention, electric circuit, magnetism" (n=14) and "Sky" (n=14), "Soil" (n=13), "Light" (n=12), "Inanimate and animate nature" (n=11), "Elements" (n=10), "Time" (n=10), "Measure" (n=10) and "Floating-Flying" (n=10), "Swimming-Sinking" (n=7), "Sustainability, ecological footprint" (n=6) and "Water" (n=6), "Dealing with people with special needs" (n=5), "Forest" (n=5) and "Weather" (n=5), "Hygiene measures in everyday situations" (n=4) and "Learning field Time" (n=4), "Sounds and noises" (n=3), "Learning field Numbers" (n=2), "Learning field Patterns and sequencies" (n=2), "Learning field Space and Shape" (n=2), "Learning field Sorting and classifying" (n=2), and "Nature observations" (n=2). An overview of these results can be seen in Figure 4.

5 CONCLUSIONS

The Teaching about the didactic implementation of STEM topics in the training of elementary teachers is anchored in the curriculum in the subjects Applied Mathematics, Applied Natural Sciences, Biology and Ecology, Chemistry and Physics of the vocational secondary schools in Austria. In comparison, the experiences of 111 interviewed elementary school teachers show that the content has not been taken up and, above all, has not always been worked on in terms of how it can be integrated in the elementary schools. Observations of nature, weather and sound and noises stand out as topics that were more dealt with in the class. However, there are also topics where not even 20% of elementary educators feel prepared, to include it in there everyday work in elementary school. A clear picture emerges from the study: the experiences of the elementary educators do not for the most part match the content from the curriculum that is actually mandatory to teach. Accordingly, it can be concluded that more than 2/3 of the elementary teachers were not sufficiently prepared by the training alone for the teaching of STEM content by the school.

6 DISCUSSION

Looking at the growing shortage of STEM specialists, it is obvious to support projects to spark the children's interest in STEM. Introducing children to the fascinating aspects of STEM content at an early age is an important step for children to develop a positive association with this branch of science (Patrick et al., 2009; Fleer et al., 2006; Hassan et al., 2019). However, in order for students to experience such content in the most positive and affirmative way possible, basic training for pedagogues from a subject oriented as well as a didactic point of view is necessary (Buchter et al., 2017). Nevertheless, elementary school teachers have little training to transfer their STEM knowledge into their practice (Clements et al., 2013). As the study shows, this is also the case in Austria: Didactic STEM training does not sufficiently take place as part of the education of elementary teachers. It is therefore even more important to provide further training that conveys both the professional expertise and the practical transfer that is lacking, as the questionnaires indicate.

Moreover, the results show how unprepared elementary teachers feel for the STEM subjects. Corresponding to the results of previous scientific studies it was shown that the teachers were mostly prepared for teaching observations of nature in elemen-

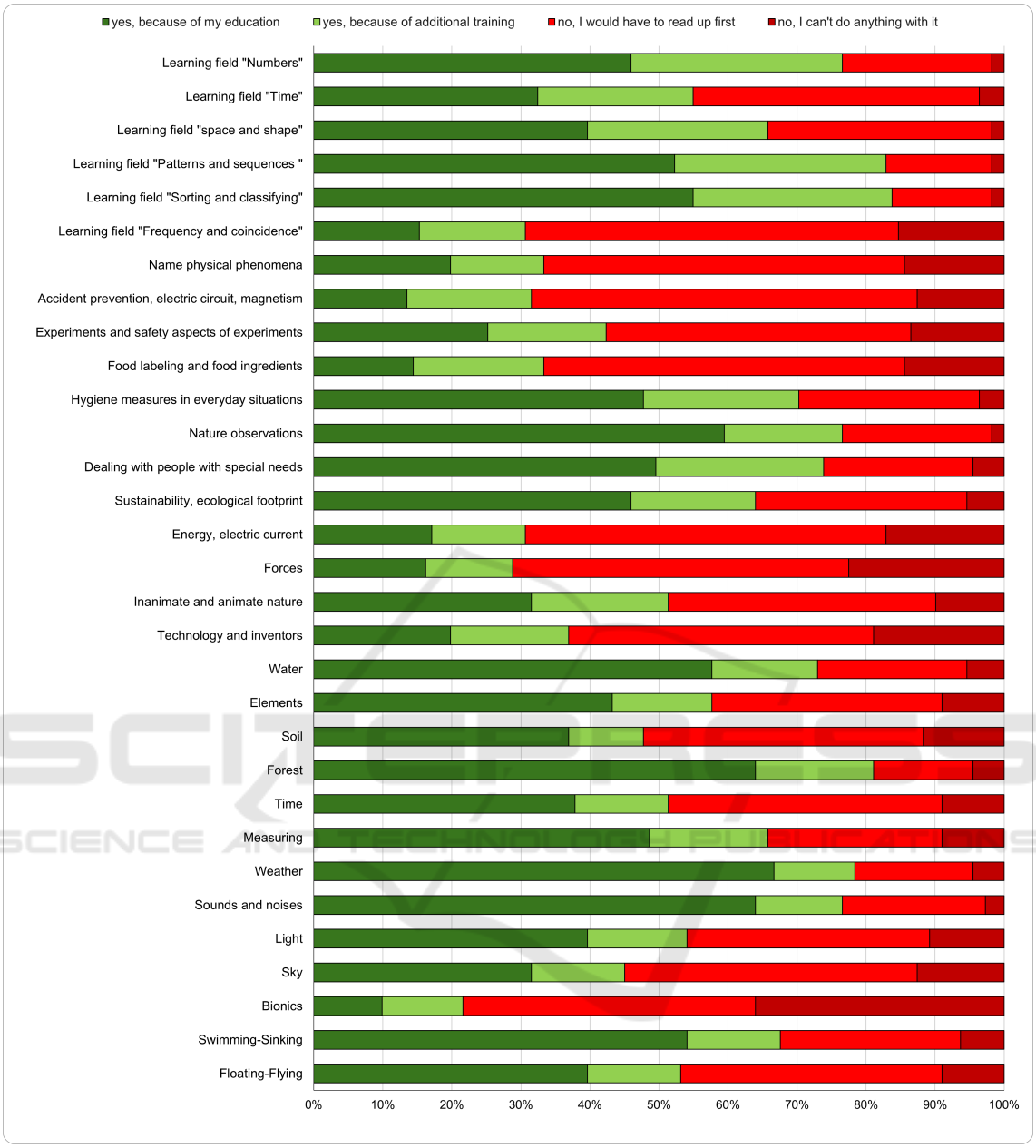

Figure 4: Overview about the teachers' self confidence in STEM implementation in elementary schools regarding the curriculum's topics.

tary classes (Lück, 2018). In most subjects the transfer to the practice was missing to non existent. A reason for this lack could be the training of teachers working at the secondary schools to educate future elementary school teachers. They are educated in a specific subject, such as Physics,Chemistry or Maths and do not have to show any previous training or practice in the field of elementary education. In this context, the question arises as to how teachers without experience in this area are supposed to convey the didactic transfer to the professional field of elementary school teachers.

Furthermore, the issue surfaces whether the teaching of STEM topics should not actually be part of special didactic subjects and not the science subjects, as is the case, for example, with language aspects. This results in a call for a revision of the curriculum for STEM subjects and in line with the last paragraph, didactic or better and more specific training for teachers of STEM subjects.

Additional, there is the problem that the students in the vocational secondary education have to go through the topics for the early final examination (part of the Matura) in one of the science subjects (incl. Geography, excl. Mathematics). As a result, the content related aspect of the STEM curriculum predominates in contrast to the options of the pedagogical implementation.

In sum, the study shows that the education in the vocational secondary school does not sufficiently train the elementary teachers in the area of implementation of STEM topics. As mentioned before, the lack of training of their teachers in the Educational Institutes for Elementary Pedagogy, the focusing on the Matura and therefore less time for transferring their knowledge and implement it the elementary schools, and the curriculum of the STEM subjects as well as Didactic in vocational secondary school might be reasons for this issue. Furthermore, for the already trained elementary teachers, training in the area of STEM subjects would not only be recommendable but also indispensable in order to enable a high-quality educational offer in the area of STEM in elementary schools. Looking at the long way of revising the curriculum, the lack of training provides a sensible opportunity for elementary teachers in the STEM field. It is important to include the results of the study and to design a teacher training course that encourages and enables elementary teachers to implement STEM in elementary school. The results of this study cannot be generalized to all worldwide forms of training for early childhood educators because the collected data was limited to institutions and early childhood educators within Austria. Additionally, the educators who filled out the questionnaires voluntarily participated and therefore may not necessarily be representative of educators from other types of training and other countries.

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