TEACHERS' PERSPECTIVE ON THE PREMISES AND PRIORITIES OF STEM EDUCATION

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1. SUMMARY

STEM education has become one of the main priorities ar European level closely connected to countries global score related to competitivness.

The present document reflects the principles and conclusions of the methodology and the research report on ***Teachers' Perspective On The Premises And Priorities Of STEM Education***, as outputs of the research activity undertaken in Romania between 2017-2019 within the Horizon 2020 Scientix3 project.

The first part, the methodology represents the backbone of the research-evaluation activities and includes: the context of the investigation, the object and mandate of the research, the sample, the purpose and the objectives of the research-evaluation, the necessary tools for the data collection, the evaluation stages, the preliminary structure of the final report, the use of the results..

The evaluation methodology was intended for use by the Scientix project team within the University of Bucharest to guide the evaluative research on educational practices from STEM disciplines in Romania at all educational levels and as a reference for (1) the development and calibration/identification of the research-evaluation tools, (2) the conduct of the investigation: the application of the tools and the data collection, (3) development of research products: research-evaluation report, articles, presentations. The process of designing the research was the first step in a succession of five main constituent elements of an investigative cycle: (1) developing the methodology, (2) identifying standardized tools in relation to the objectives of the research, (3) collecting data, centralization and interpretation, (5) drafting and revising the final report.

The research report draws on the analysis and interpretation of 259 responses offered by STEM teachers in pre-university education to the T-STEM questionnaire developed by Friday Institute for Educational Innovation, North Carolina State University (2012). Its aim was to provide a grassroots perspective on how teachers view seven constructs that are evaluated through the questionnaire: personal teaching efficacy and beliefs, teaching outcome expectancy beliefs; student technology use; STEM instructions; 21st century learning attitudes; teacher leadership attitudes; STEM career awareness. Also, the report summarises key findings and recommendations reached in the end of the analysis and interpretation process.

Both the methodology and the final report are to be made available to decision-makers in the education system as a possible benchmark for new education policies geared towards quality, innovation and efficiency in science education.

Last but not least, the methodology, assessment tools and report are to be available to teachers from the target group and other practitioners, education researchers, academics, representatives of NGOs and companies with a role in education, etc.

2. CONTEXT

The investigative approach was carried out within the framework of the international project Scientix, coordinated at European level by European Schoolnet, constituting distinct activities within the implementation plan in Romania for the period 2017-2018: T5.2-nRO22- Research methodology design and implementation and T5.2-nRO23- Study Report.

The conceptual framework of the research was based on data and information on STEM training and its context, as evidenced by evaluation reports and recommendations developed in recent years in Europe and at national level.

2.1. Premises and determinations

The World Competitiveness Report 2015-2016 (Klaus Schwab, World Economic Forum), which provides an overview of competitiveness in 140 countries, reveals that education reform must be a key focus of the agenda governments to increase the competitiveness of the economy today, an economy based on innovation, technology and entrepreneurship.

Relatively recent studies indicate the main determinations of science education in a formal context. Some synthetic extracts from these materials give us useful information to circumscribe the investigative approach:

- Recommendations for Educational Policies, material developed in November 2017 within the European TTTNet project (Teamwork, Training and Technology Network);
- Science, Technology, Engineering and Mathematics Education: A Survey of Challenges in Europe, a booklet published by European Schoolnet in 2011, a starting point for the European Scientix program;
- ASPIRES - Young people's science and career aspirations, age 10-14, study conducted in the UK in December 2013.

2.2. The framework offered by the Scientix project

The investigative approach continues the research activity initiated within the previous cycle of Scientix. The 2015 research sought to obtain relevant data on national initiatives with an impact on raising student motivation towards STEM education and choosing a professional career in this field. The tool used in this research was a questionnaire addressed to the Scientix National Contact Points that were responsible from the perspective of the Ministry of Education or the national reference agency for the STEM domain.

2.3. Legitimacy and opportunity of research

Several features justify this investigative approach:

- The need for qualified specialists in STEM-related fields to truly support the development of a dynamic and innovative knowledge-based society and economy;
- Existing initiatives to integrate formal education with institutions, initiatives and resources supporting science education through non-formal approaches; developing and expanding non-formal education programs for STEM;
- Support networks made up of scientists, researchers and practitioners, through punctual support, directly or indirectly, through citizen science projects, etc.;

- Recent documents on European education recommendations and policies, as well as the increasing allocation of financial resources / sources of funding from the European Commission for projects to promote, train, increase the attractiveness of science and science education;

- Repeated reports in the Romanian public space on the programs and projects carried out or in progress, the focus on the transfer of the results of the scientific research projects and their extension within the educational system;

- The existence in Romania of extensive networks and among the most active at European level of teachers attached to different initiatives and projects (e.g. Scientix, ESERO, ROEDUSEIS, eTwinning, etc.) emphasizing the need to connect and participate in organizing and developing the system.

3. SUBJECT OF EVALUATION AND MANDATE

3.1. Evaluation object

The present assessment focuses on the current practices teachers are using to develop students' STEM competences and the ways in which they are influenced by decision-makers' support; existing resources; teachers' level of education; attitudes and perceptions of teachers and students towards STEM disciplines and their role in professional training.

Thus, the evaluation research approach regards the prescribed and the actual curriculum, the hidden curriculum, the STEM teacher training programs, the teachers' expectations at different moments of the professional career, the recommendations of the experts and practitioners of the field, the school performance in the STEM disciplines.

3.2. Mandate

More than a wishful goal, the evidence-based foundation of STEM educational policies is a necessity and an imperative.

In the context of the Scientix project, the project team at the University of Bucharest (the Faculty of Psychology and Educational Studies and the Faculty of Physics) elaborated an evaluation research methodology, identified the necessary tools and applied them on a specific sample of teachers.

The main beneficiaries are the decision makers and experts who contribute to the development of national, local and institutional educational policies.

Potential users: teachers; institutions involved in initial and in-service teacher education processes; national and European institutions interested in research results to perform comparative and system analyzes; funding institutions for specific programs in the field; potential partners in the development of educational programs in the field (research institutes, NGOs, companies); the direct and indirect beneficiaries of the Romanian education system.

4. THE ENDS OF THE EVALUATION RESEARCH

4.1. Scope

The aim of the investigation is to highlight the extent to which current STEM teaching practices in pre-university education contribute to the formation and development of students' STEM competences.

4.2. Objectives

The objectives of the evaluation research are:

- O1. Description of the current situation of STEM education in Romania (goals, status of the disciplines and their integration, orientations, evolution, trends) and the results in the field (school performance, evolution in TIMSS, absorption of funding for scientific research, etc.);
- O2. Identifying teachers' beliefs and attitudes about self-efficacy in their professional practice;
- O3. Assessing beliefs about how teacher activity affects student learning;
- O4. Assessing the degree of use of technology by students in their learning approach related to STEM disciplines;
- O5. Identifying teachers' perceptions regarding the application of innovative pedagogies in teaching of STEM disciplines;
- O6. Assessing teachers' own attitudes about the 21st century skills, the leadership skills of the teaching staff;
- O7. Assessing the awareness of STEM careers.

5. TOOLS

The investigative strategy is related to the priorities and trends identified in the area of science education, the characteristics of the investigated population and the actual investigation possibilities of the project team. Two investigative techniques are used: document analysis and standardized questionnaire survey to reveal views, underlying values, attitudes and trends in teaching practice, training content, available or needed resources, and the opportunity and the value of STEM education.

5.1. Presentation of the instruments

The analysis of the documents, initiated at the stage of designing the research methodology, was followed in parallel with the analysis and interpretation of the results obtained through investigation and interviews, in order to support the conclusions and recommendations with theoretical references, comparative data, trends in the field.

Aims: (1) exploratory activity, domain analysis to build investigation methodology, (2) harvesting additional information to those obtained through methods of opinion investigation, (3) validation of results by correlation with the theories of the science of education.

The questionnaire survey was chosen to reach a significant number of teachers. Teacher questionnaire for STEM subjects (T-STEM, Appendix 1) was applied online. The grids that compose it are standardized tools developed by the Friday Institute for Educational Innovation, North Carolina State University (2012) and the research team has the institution's agreement for their use in the present research.

Table 1: T-STEM Survey Summary

Construct	Measurement Application
Personal Teaching Efficacy and Beliefs	self-efficacy and confidence related to teaching the specific STEM subject
Teaching Outcome Expectancy Beliefs	degree to which the respondent believes, in general, student-learning in the specific STEM subject can be impacted by actions of teachers
Student Technology Use	how often students use technology in the respondent's classes
STEM Instruction	how often the respondent uses certain STEM instructional practices
21st Century Learning Attitudes	attitudes toward 21st century learning
Teacher Leadership Attitudes	attitudes toward teacher leadership activities
STEM Career Awareness	awareness of STEM careers and where to find resources for further information

The Personal Teaching Efficacy and Beliefs (PTEB) construct and the Teaching Outcome Expectancy Beliefs (TOEB) constructs were derived from a well-known survey of science teachers, the Science Teaching Efficacy Belief Instrument, or the STEBI (Riggs & Enochs, 1990). The Student Technology Use construct was developed from the Student Technology Needs Assessment, or STNA (SERVE Center, 2005). The STEM Instruction construct was based on items that were developed by The Friday Institute and used in a statewide evaluation of the professional development activities of North Carolina's Race to the Top grant (Corn, et al., 2013). The 21st century learning attitudes construct was adapted from the Friday Institute's Student Learning Conditions Survey (2011). Finally, each item in the Teacher Leadership Attitudes construct was taken from the North Carolina Department of Public Instruction's professional standards for educators (2012).

Purpose: to collect quantitative information to build responses to evaluation questions and test hypothesis research.

6. SAMPLE

The on-line application of the T-STEM questionnaire was an important empirical situation that could provide some clues as to the collection of meaningful, consistent and useful empirical data given the qualities of the tools used. In this study, the research team did not want to sample the target population, getting thus by the process of collecting the answers a sample of opportunity, made up of those people who chose to fill in the research tool we used. This method of investigation has some obvious advantages and disadvantages. As far as the benefits are concerned, it allows investigating as many people as possible in the target population. Of course, from a methodological perspective, the absence of a sampling rule may cause distortions caused by exogenous factors of research, such as the quality of databases with contact data held by the investigative team, the availability of people to complete a research tool quite the level of individual interest in participating in such research, and others. We believe, however, that the influence of such factors is inherent in any social research approach, regardless of the sampling method. In addition, the use of an on-line research tool offers the opportunity to record a relatively large number of responses, higher than would be possible by applying face-to-face questionnaires.

Individuals were contacted individually by using e-mail. Scientix and eTwinning on-line professional networks had also been used, as well as other ways of distributing information through the personal networks at the disposal of the research team.

Following these efforts, a number of 259 Romanian teachers responded to the invitation to contribute to the formation of a current picture of the attitudes of the teachers in the pre-university education system towards the training activity, the results of the pupils' learning and their attitudes towards the use of technologies and current STEM education – physics (20.1%), chemistry (20.1%), biology (5.4%), computer science (16.6%), technology (16.6%), mathematics (28.6%) to which 24.7% come from primary education that cover everything related to math and natural sciences.

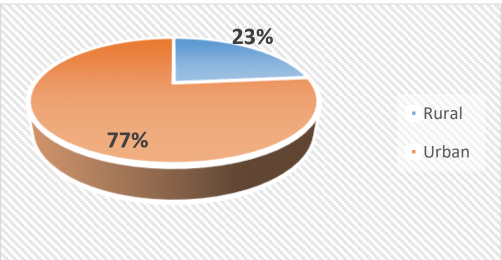

Figure 1: Distribution: rural – urban

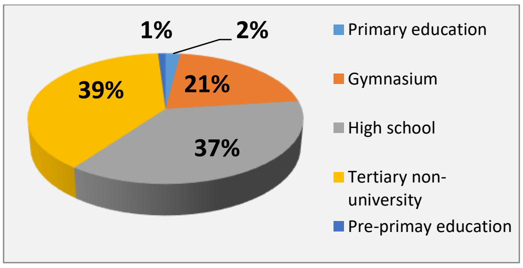

Figure 2: Distribution: educational level

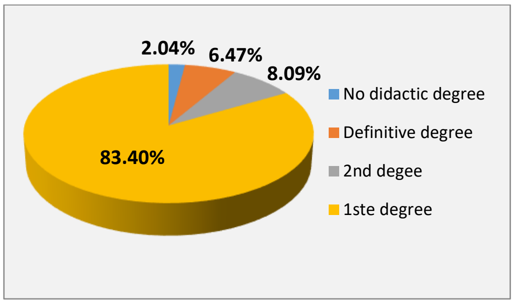

Figure 3: Distribution: teachers

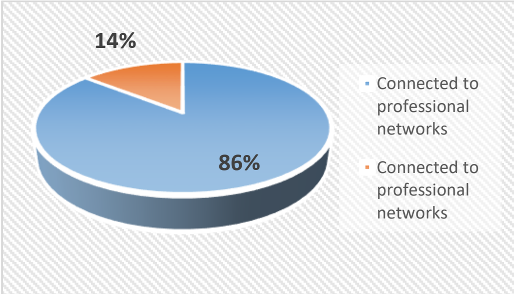

Figure 4: Distribution: connected / not connected

The disproportion of the number of teachers teaching mathematics in relation to the other categories can be explained also by the higher number of math teachers within the education system, due to the number of math classes in the curriculum. As in most European countries, mathematics in Romania is taught as a compulsory discipline in both primary and lower secondary education, representing the main subject of the STEM category. At secondary level, high school, the situation tends to be diversified according to the profile and specialization of the studies.

In primary education, mathematics is taught in the first two interdisciplinary grades alongside other STEM disciplines within a discipline named Mathematics and Nature Sciences, while in the last three grades of this cycle it benefits of a disciplinary approach. In secondary lower-secondary education, pupils begin to be enrolled in other STEM disciplines (Biology - 5th-8th grade, Physics - 6th-8th grade, Chemistry - 7th-8th grade, Technological Education and Practical Applications, Informatics and ICT - 5th-8th grade), mathematics continuing to keep a constant number of 4 hours/week. Mathematics is a compulsory discipline for the graduation of the gymnasium cycle that counts for the admission at high school and for certain profiles and specializations it is a compulsory discipline within the baccalaureate exam (the end of the 12th grade) which counts for admission to university studies.

7. ANALYSIS AND INTERPRETATION

7.1. Personal teaching efficacy and beliefs

Teachers' beliefs and attitudes towards their own training activity were captured by a series of investigative items related to the design, development and improvement of didactic activities aimed at STEM students' knowledge, skills and attitudes.

Related to the first construct Personal Teaching Efficacy and Beliefs – we can see that in general, teachers have a good, positive belief regarding their personal teaching efficacy. In all cases the Agree/Strongly agree is over 86% with a single exception *I wonder if I have the necessary skills to teach science*, the only item that is negatively worded. All other items are positively worded. For this item the scores are Agree/Strongly agree (48.98%), Disagree/Strongly disagree (36.84%) and Neither Agree nor Disagree (14.18%). We interpret the results at this item conservatively however it is important to notice the differences between the two subplots – the pre-secondary teachers seem to be reserved towards their skills to teach science (66.66% - Agree/Strongly agree), while only 43.68% of the secondary teachers doubting this skills. The results in this item are supported by those to I am confident that I can explain to students why science experiments work (91.22% - agree/strongly agree for pre-secondary teachers and 97.36% - agree/strongly agree for secondary teachers) and I am confident that I can answer students' science questions (89.47% - agree/strongly agree for pre-secondary teachers and 98.94% - agree/strongly agree for secondary teachers). Interestingly enough the scores change quite significant with greater percentage in favour of pre-secondary teachers in the case of the item related to students' motivation I know what to do to increase student interest in science (96.49% - agree/strongly agree for pre-secondary teachers and 91.57% - agree/strongly agree for secondary teachers).

Table 2: Personal Teaching Efficacy and Beliefs

	Primary ed. (n = 57)		**Secondary ed. (n=190)**		**Total (n=247)**	
	Disagree/ Strongly Disagree	Agree/ Strongly Agree	Disagree/ Strongly Disagree	Agree/ Strongly Agree	Disagree/ Strongly Disagree	Agree/ Strongly Agree
I am continually improving my science teaching practice.	1.75%	98.24%	1.05%	97.89%	1.21%	97.97%
I know the steps necessary to teach science effectively.	1.75%	94.72%	1.05%	95.78%	1.21%	95.54%
I am confident that I can explain to students why science experiments work.	1.75%	91.22%	1.05%	97.36%	1.21%	95.95%
I am confident that I can teach science effectively.	1.75%	98.24%	1.05%	97.89%	1.21%	97.97%
I wonder if I have the necessary skills to teach science.	15.78%	66.66%	43.15%	43.68%	36.84%	48.98%
I understand science concepts well enough to be effective in teaching science.	1.75%	96.49%	1.57%	97.89%	1.61%	97.57%
Given a choice, I would invite a colleague to evaluate my science teaching.	7.01%	82.45%	3.15%	87.36%	4.04%	86.23%
I am confident that I can answer students' science questions.	1.75%	89.47%	0.52%	98.94%	0.8%	96.76%
When a student has difficulty understanding a science concept, I am confident that I know how to help the student understand it better.	3.5%	94.73%	0%	99.47%	0.8%	98.38%
When teaching	1.75%	94.73%	0.52%	98.42%	0.8%	97.57%

	Primary ed. (n = 57)		Secondary ed. (n=190)		Total (n=247)	
	Disagree/ Strongly Disagree	Agree/ Strongly Agree	Disagree/ Strongly Disagree	Agree/ Strongly Agree	Disagree/ Strongly Disagree	Agree/ Strongly Agree
science, I am confident enough to welcome student questions.						
I know what to do to increase student interest in science.	1.75%	96.49%	2.63%	91.57%	2.42%	92.71%

In the end, we cannot feel but a little puzzled by the results at this construct. However, it is in line with the results of the OECD TALIS report (2013) based on teachers' beliefs, perceptions and opinions which concludes that teachers in Romania and Malaysia feel the best trained among teachers in 33 countries, both in the content of teaching and in pedagogy. The last places are Finland and Japan, where teachers feel the least trained. However, the teachers' opinion about their professional training contrasts strongly with the results obtained by the students in another test organized by the OECD: PISA tests show that Romania ranks 45 out of 65, Malaysia on 52, while Finnish students are 12 and Japanese students ranked 7th.

7.2. Teaching Outcome Expectancy Beliefs

Defining learning outcomes today is a focal point of interest and, at the same time, a challenge to institutions with responsibilities in the area of curricular reform development. In the context of this research, we will only mention the three reference frameworks developed at European and international level: the key competences set (European Commission, 2005, 2018), 21st Century Learning and OECD Learning Framework 2030 (2018). By intersecting the perspectives of each of these frameworks, we can identify three distinct categories of abilities: (1) learning and innovation skills: critical thinking, creative thinking, cognitive flexibility, problem-solving skills, decision making, collaboration, communication; (2) digital skills; (3) life and career skills: initiative and self-development, social and intercultural interaction, productivity and responsibility.

In relation to STEM disciplines, the expectation is for students to learn scientific, technical concepts specific to each discipline, to demonstrate the ability to integrate theory and practice using critical thinking and analytical skills. In addition, we expect students to develop their ability to solve complex problems, team work, and communicate ideas effectively, both orally and in writing. Most STEM disciplines also contribute to developing a sense of professional responsibility, including ethics and learning to learn to support lifelong learning. Recent studies link STEM disciplines to academic and professional successors regardless of the later chosen field - critical thinking, creativity, cognitive flexibility, etc.

In this context, teachers' expectations of learning outcomes, the perception of their own role in the context of academic success or school failure is relevant.

The merits of learning progress are largely attributed to teachers' own efforts - 62% are partially in agreement and 13% are totally in agreement. A quarter of teachers also admit other variables that could contribute to outstanding results.

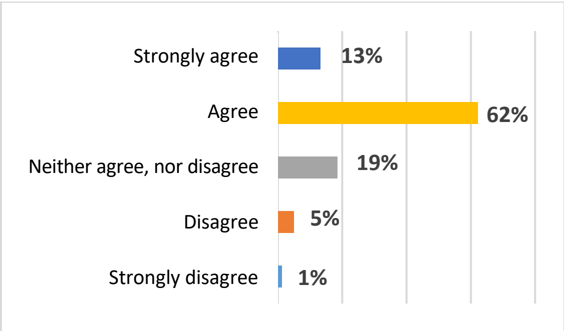

Figure 4: "When a student does better than usual in STEM, it is often because the teacher exerted a little extra effort."

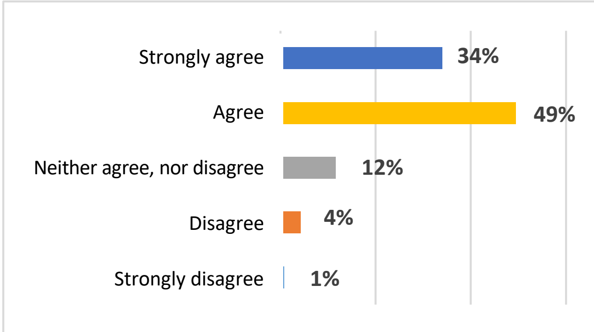

Figure 5: "The inadequacy of a student's STEM background can be overcome by good teaching."

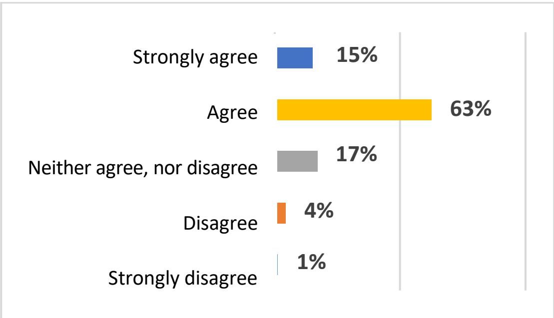

Figure 6: "When a student's learning in STEM is greater than expected, it is most often due to their teacher having found a more effective teaching approach."

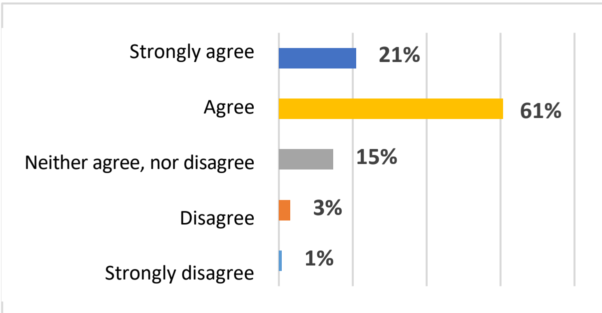

Figure 7: "The teacher is generally responsible for students' learning in STEM"

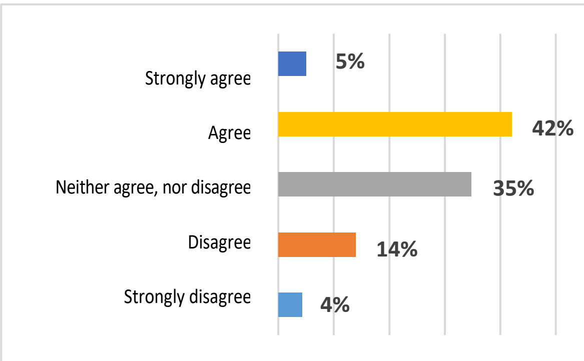

Figure 8: "If students' learning in STEM is less than expected, it is most likely due to ineffective STEM teaching."

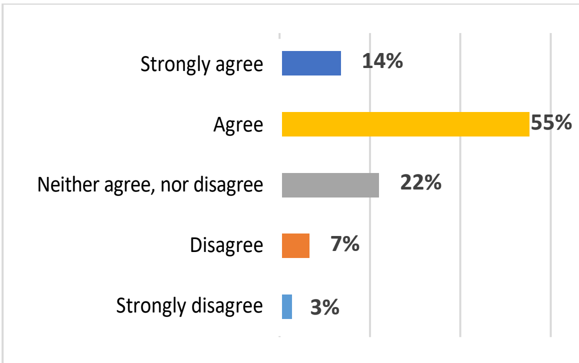

Figure 9:" Students' learning in STEM is directly related to their teachers' effectiveness in STEM teaching."

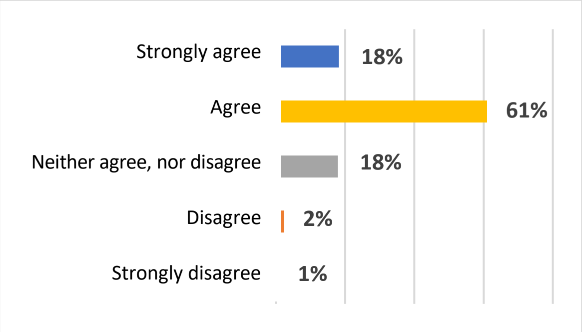

Figure 10: "When a low achieving child progresses more than expected in STEM, it is usually due to extra attention given by the teacher."

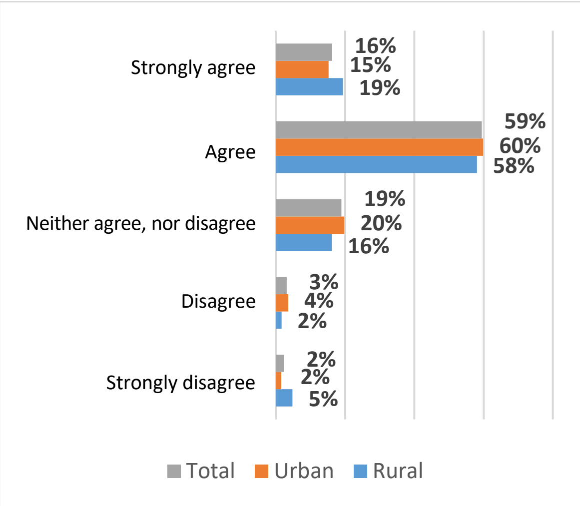

Figure 11: "If parents comment that their child is showing more interest in STEM at school, it is probably due to the performance of the child's teacher."

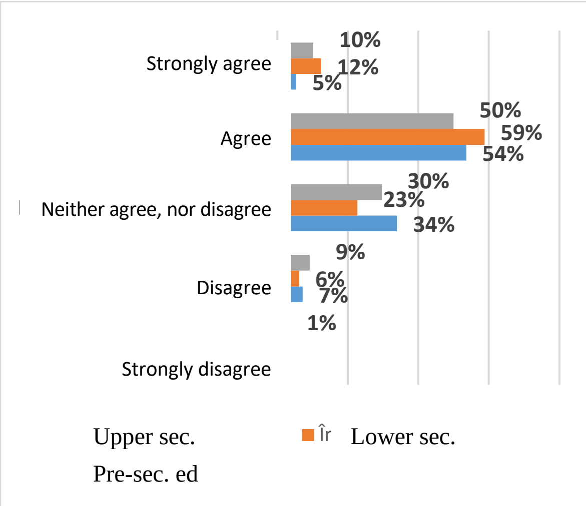

Figure 12:" Minimal student learning in STEM can generally be attributed to their teachers."

Teachers tell us that the interest in STEM is today determined by factors that do not necessarily include school and teacher. Surprisingly, primary school teachers consider that the external influences of the school have a larger share at 6-10 years, close to the opinions of the high school teachers, while the gymnasium is to a greater extent the stage in which the teacher can influence the interest and can increase the attractiveness of STEM domains for students.

7.3. Student Technology Use

Most of the times considered essential tools for supporting an effective, applied, anchored and forward-looking education pathway, ICT tools are increasingly encountered in learning situations in Romanian education system. To them our investigation dedicates a series of questions, with the mention that in this context ICT is not an object (or content) of teaching, but a support that facilitates teaching, learning and assessment approaches to various disciplines (including Informatics or Technologies). The questions address the extent to which students use information and communication technologies during the teaching and learning activities proposed by teachers.

Urban ecosystems are privileged from this point of view, schools in cities being better equipped with computers and having better connectivity than rural schools. This enables students to use a variety of information and communication technologies in the education situations proposed by teachers in STEM disciplines: digital resources (online), tools to increase efficiency and productivity, tools that enable data visualization, research tools and communication media.

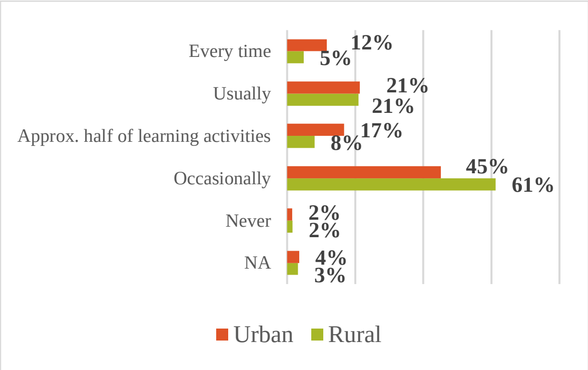

Figure 13: The extent to which students are using ICT in STEM classes. Rural-urban distribution

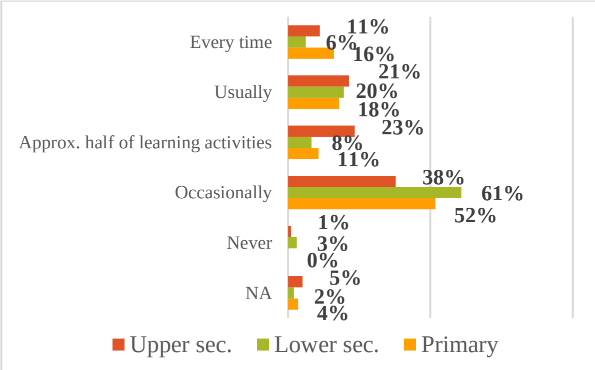

Figure 14: The extent to which students are using ICT in STEM classes. Distribution by cycles

The reasons for which an education situation calls for new technologies can be very diverse, with the most prominent categories being: (1) collaboration – the use of ICT to communicate and collaborate with other colleagues, possibly beyond the classroom, in homework or in eTwinning collaborative projects, as well as (2) documentation – use of technologies to access online resources and information as part of the educational activities carried out. Teachers of STEM subjects propose to students both uses, in a fairly equal degree.

Conclusions from data analysis:

- Technologies are increasingly present in educational situations in Romanian education, schools in the urban environment being privileged in this respect. They are better equipped with computers and higher connectivity than rural schools.
- One in ten urban teachers proposes students with advanced tools every hour they perform at STEM disciplines.
- In a percentage we consider very high, half of the gymnasium teachers declare that they are not the case (4%) or never use (45%) simulations, databases, satellite imagery or similar tools in the training activities they carry out with the pupils.
- Three quarters of pupils work on STEM projects, with ICT support, at least occasionally, the distribution being balanced, contrary to expectations, by education cycles.

- A fair distribution is also to be met with regard to the purposes for which digital resources and new technology tools are integrated into STEM discipline training activities.

7.4. STEM Instructions

One of the main objectives of the research was to better understand how teachers implement STEM-specific training methodologies to develop relevant learning outcomes. At international as well as national level, we are beginning to see new methodologies that are developed and applied in the teaching of many STEM disciplines. In Romania, the methodological suggestions in the school curriculum emphasize the importance of intuitive methodologies especially in primary and gymnasium education, research methodologies, projects that support argumentation of reasoning or problem-solving methods, the interpretation of graphs, but also those that propose the use of software without any exemplification of any kind.

Specifically, the research sought to reveal and measure the extent to which students are involved in a series of activities that lead to the development of science-specific competences in "classroom" or extra-curricular training (clubs, summer schools, etc.). Although the practices/ methodologies reflected by the items are among those reinforced by present research in the field as having an impact in the development of the learning results envisioned for the STEM area, teachers' responses reflect a different reality. Only Work in small groups exceeded 50% - Usually/ Every time and that because pre-secondary teachers seem to use this method quite frequently 68.42%. Another general remark on the results as a whole for this construct is that most of the times there is a smaller gap between Never/ Occasionally and Usually/ Every time, which proves that the population of teachers is quite biased regarding the practices in the classroom. The last general remark relates to the first item Develop problem-solving skills through investigations where 49.79% of teachers state that they never or only occasionally use this method although the investigation competence is in the first three positions in all STEM syllabuses.

Taking a look at the results related to the two subplots – pre-secondary and secondary education level - there are some interesting data that should be discussed. For pre-secondary education the first three methods that are mostly used are: Work in small groups, Engage in content-driven dialogue and Complete activities with a real-world context. Interestingly enough for secondary teachers the first two methods are the same though with significant lower percentage: Work in small groups, Engage in content-driven dialogue and Choose the most appropriate methods to express results and Reason quantitatively. However, the first two methods is easy to see that they are not necessary specific to STEM education, while having a more cross-curricular character and unstructured character. On the other hand, the method less used in both pre-secondary and secondary education seems to be Recognize patterns in data. Another methodology that seems to be less adopted in the classroom is Create reasonable explanations of results of an experiment or investigation. However, in this case it is interesting to notice the difference in the two subplots as 45.61% of pre-secondary teachers state that they usually/ every time use it while only 33.15% of the secondary teachers state the same. Interestingly enough there is a significant difference in using Make predictions that can be tested where 47.36% of pre-secondary teachers confirm to use usually/ Every time, but only 39.47% from secondary teachers seem to use.

Table 3: STEM Instructions

	primary ed. (n=57)		secondary ed. (n=190)		total (n=247)	
	Never/ Occasion.	Usually/ Every time	Never/ Occasion.	Usually/ Every time	Never/ Occasion.	Usually/ Every time
Develop problem-solving skills through investigations	52.63%	35.08%	48.94%	36.31%	49.79%	36.03%
Work in small groups.	12.28%	68.42%	31.57%	45.78%	27.12%	51.01%
Make predictions that can be tested.	36.84%	47.36%	44.73%	39.47%	42.91%	41.29%
Make careful observations or measurements.	36.84%	40.35%	38.94%	40.52%	38.46%	40.48%
Use tools to gather data.	40.35%	40.35%	35.26%	42.1%	36.43%	41.7%
Recognize patterns in data.	56.14%	29.82%	54.73%	24.73%	55.06%	25.91%
Create reasonable explanations of results of an experiment or investigation.	38.59%	45.61%	47.36%	33.15%	45.34%	36.03%
Choose the most appropriate methods to express results	43.85%	43.85%	38.94%	42.63%	40.08%	42.91%
Complete activities with a real-world context.	33.33%	50.87%	41.57%	38.94%	39.675	41.7%
Engage in content-driven dialogue.	28.07%	52.63%	33.15%	43.68%	31.985	45.74%
Reason abstractly.	31.57%	42.1%	34.73%	38.94%	36.43%	37.24%
Reason quantitatively.	31.57%	31.57%	29.47%	42.63%	29.95%	40.48%
Critique the reasoning of others.	28.07%	43.85%	36.84%	40.52%	34.81%	41.29%
Learn about careers related to the instructional content.	49.12%	38.59%	40%	42.1%	42.1%	41.29%

Also, in relation with other studies that focused on differences within STEM disciplines (Nistor, 2018), we also consider an analysis of how STEM strategies are used in mathematics as opposed to other disciplines. For all categories of strategies listed, the percentages resulting from the mathematical teacher response analysis are placed below the percentages resulting from the analysis of the responses provided by the teaching staff teaching the other STE subjects ranging from 2.09% to the abstract reasoning up to 17.78 % to Learn about career / career paths in the discipline.

7.5. 21st Century Learning Attitudes

For years, education systems have claimed that upwards 80% of their graduates are ready for work. Unfortunately, employers report much lower, less than 20%, graduates who are ready for work. In 2002, the Partnership for 21st Century Learning (formerly the Partnership for 21st Century Skills) was set up as a coalition whose purpose was to bring the business community, educational leaders and policymakers together to initiate a debate on the importance of the 21st century skills for all students. Further studies included ones undertaken by Stanford Research Institute International and the Carnegie Mellon Foundation focused on identifying the skills needed for success in the workplace and the extent to which new graduates entering the labor market had those abilities. It turns out that the skills gap was not lack of knowledge or technical skills (Basic Knowledge). Instead, the gap was that graduates had soft skills deficits (Applied Skills). Another study led by Alliance for Excellent Education, assumed that soft skills predicted high school and college completion. Their research has shown that 95% from 3 to 11-year-olds who scored in the top 20% of their self-control soft skills graduated from high school. Only 58% of the students who scored in the bottom 20% of ”self-control” graduated. (Young, 2013)

These arguments contribute to understanding the relevance of research data for this section, the larger framework to which it should be related, and the meaning of the conclusions.

To illustrate the attitudes towards 21st century skills, teachers were generally asked to indicate, using a five-step scale, the importance of providing students with working opportunities in which to practice the skills they need today in professional environments. For a comparative illustration, we transposed the descriptive scale into a numerical form and we calculated the average of each skill in the proposed list: Strongly disagree -2, Disagree -1, Neither Agree, nor disagree 0, Agree 1, Strongly agree 2.

The most valued learning activities are those related to individual performance:

- Manage their time wisely when working on their own - 1.71
- Produce high quality work - 1.71
- Set their own learning goals - 1.71.

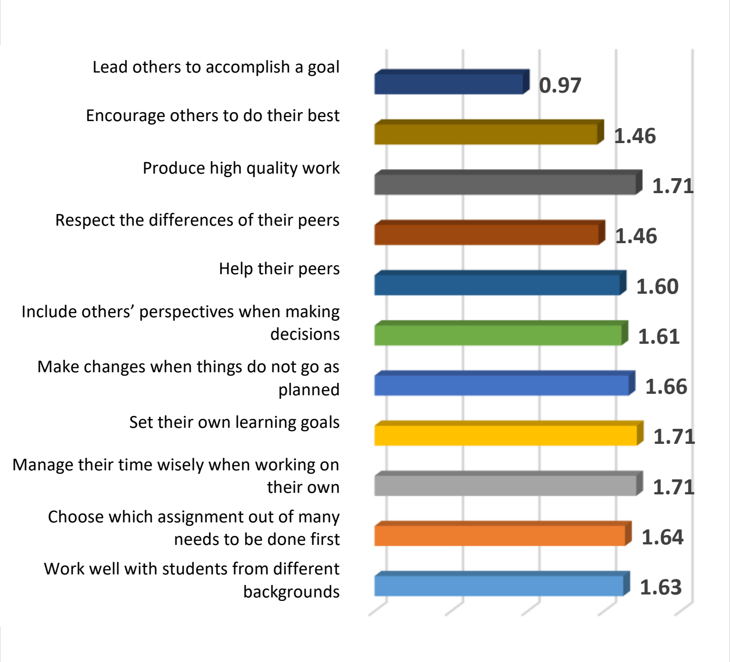

Figure 15: „I think it is important that students have learning opportunities to…". The media of teacher preferences

The responses offered by STEM discipline teachers show that they do not value leadership so much (average of 0.97 on a scale of -2 to 2). Also, attributes that are prerequisites for inclusion and cooperation have earned the least credit, probably less concerned with designing learning situations:

- Lead others to accomplish a goal - 0.97
- Encourage others to do their best - 1.46
- Respect the differences of their peers - 1.46
- Help their peers - 1.60.

7.6. Teacher Leadership Attitudes

Katzenmeyer and Moller (2001) highlight three aspects of educational leadership: (1) leadership of students or other teachers: facilitator, coach, mentor, trainers, curriculum specialist, creating new approaches, leading study groups; (2) leadership of operational tasks: keeping the school organised and moving towards its goals, through roles as Head of Department, action researcher, member of task forces; (3) leadership through decision making or partnership: membership of school improvement teams, membership of committees, instigator of partnerships with business, higher education institutions, LEA's, and parent-teacher associations. (Katzenmeyer & Moller, 2001)

More specifically, at the level of the class, within the didactic activity, the leadership skills of the teacher are expresses by her/his the expertise, the way in which she/he constantly strives to optimize her/his activity, being at the same time positively oriented towards solutions.

Some of these elements of defining teachers' leadership, especially the leader's size in the classroom, are also found in the questionnaire, and the results obtained are relevant to teachers' perception of this work component.

On a scale from -2 (strongly disagree) to 2 (strongly agree), the hierarchy of leadership attributes of teaching staff generally indicates a favorable attitude towards efforts to Empower students (1.89) and to Establish a safe and orderly environment (1.82), followed closely by other similar qualities.

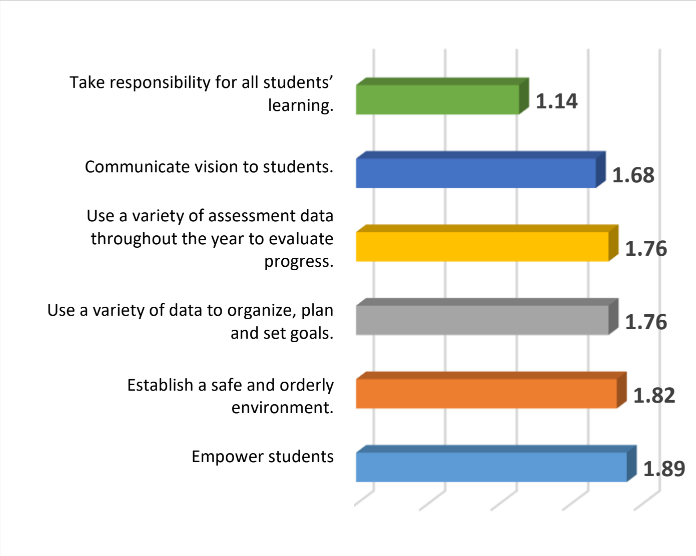

Figure 15: The importance of steps that measure the leadership of the teaching staff in general

The least appreciated attribute as belonging to the teacher as "learning group leader" is to Take responsibility for all students' learning (averaging 1.14), yet achieving a very high score close to the other listed activities.

7.7. STEM Career Awareness

In the introductory part of the detailed research report, some of the conclusions of the ASPIRES study outline aspects of the current situation that tell us why the STEM disciplines are not attractive to pupils. Particularly: (a) students often do not see the relevance/ significance of science, which seems abstract and distant (how you think); (b) most students cannot see beyond the researcher's career when it came to the sciences; they were not aware of their transferability in a wide range of careers (what you know); (c) students with limited science capital rarely have contact with scientists, so it is not surprising that they know little about the variety of scientific careers and what they are supposed to do; most significant, one cannot imagine having a job in a scientific field (whom do you know).

As a consequence, it becomes relevant how this sciences capital is built related also to the correlated professions.

An important area of interest in this context is the ability of the school to provide pupils with a clear, attractive and motivating picture of a STEM career. Teachers reveal a rather moderate confidence in their ability to guide students, with scores of about 0.69 on a scale of -2 to 2.

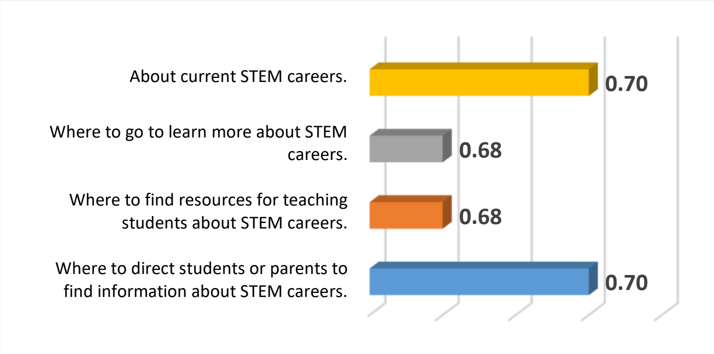

Figure 16: The extent to which teachers believe they can direct students to a STEM career

Research data is not very promising, and we think it reflects a reality. Teachers know quite little about the professional careers in STEM and, worryingly, do not find it satisfactory that they could or would know where to find information and resources to guide their students or parents.

This perspective is also supported by the previous answers to the question Learn about careers related to the instructional content from the STEM Instruction section where 42.1% of the teachers state that they use Occasional/Never involve students in learning about this subject, while only 41.29% of them do this Usually/Every time.

8. CONCLUSIONS

The development of a solid, relevant scientific understanding of pre-university school students, as well as their preparation to face the challenges of an increasing technical world, requires an exposure to specific teaching practices, beliefs and attitudes demonstrated by STEM teachers. The teachers are key agents so they should promote high self-efficacy and learning outcomes expectancy, engage in challenging but also of impact practices, well aware of the 21st century skills and the future careers in the field.

The main findings of the study conducted around the six constructs of the research tool reveal:

- Construct 1 "Personal Teaching Efficacy and Beliefs" shows that, in general, teachers have a good, positive attitude in terms of their personal effectiveness. Primary teachers appear to be more reserved about their ability to teach science than secondary school teachers. Interestingly, scores significantly change with a higher percentage in favor of primary school teachers who are more confident that they can play an important role to boost student motivation.

- Construct 2 ”Teaching Outcome Expectancy Beliefs” underlines that the merits of learning progress are largely attributed to teachers' own efforts, while the unsatisfactory results do not meet the same level of consensus on responsibility, and teachers consider that there might be other factors that impede the performance of their pupils, the teaching activity they are planning and carrying out is therefore a necessary, but not sufficient condition. Surprisingly, primary school teachers consider that the external influences of the school have a larger share at 6-10 years, close to the opinions of the high school teachers, while the gymnasium is to a greater extent the stage in which the teacher can influence the interest and can increase the attractiveness of STEM domains for students.

- Construct 3 ”Student Technology Use” demonstrates: (1) increase in the use of digital resources and new technology tools in STEM disciplines training activities to acquire 21st century skills and stimulate deep learning; (2) increasing access to and interaction with a certain degree of consistency with science professionals (researchers, inventors, theorists) and, at the same time, with the tools they use; (3) the need for a systematic and well-organized approach to the empowerment of teachers teaching subjects in the STEM area.

- Construct 4 ”STEM Instruction” proves that although the teaching practices / methodologies reflected by the items are among those validated by current research in the field as having an impact on the development of learning outcomes related to STEM disciplines, teachers' responses reflect a different reality. Only the item Working in small groups exceeded 50% - Usually / Every time and because teachers in secondary education seem to use this method quite frequently 68.42%. Another overall observation based on the responses for this construct is that there is often a smaller gap between Never / Occasionally and Usually / Every time, which shows that the population of teachers is quite biased in terms of practices employed in the classroom. The last general remark refers to the first item Develop problem-solving skills through investigations (e.g. scientific, design or theoretical investigations), in which 49.79% of the teaching staff assert that they never use this method or only occasionally, although investigative competence is in the top three positions of all STEM programs.

- Construct 5 ”21st Century Learning Attitudes” shows that the most valued learning activities are those related to individual performance: Manage their time wisely when working on their own - 1.71, Produce high quality work - 1.71, Set their own learning goals - 1.71.

  On the other hand, the responses provided by STEM discipline teachers show that they do not value leadership so much, neither inclusion nor cooperation.

- Construct 6 ”Teacher Leadership Attitudes” demonstrates a rather interesting picture, while teacher assert that they make efforts to Empower students and to Establish a safe and orderly environment, they do not assume their responsibility for the learning results of all students. The crosscheck on the answers to this construct and others relating to teachers responsibility show a consistence in their answers. The relationship between the two attributes leadership and responsibility in teachers needs further, deeper research.

- Construct 7 ”STEM Career Awareness” reveals research data that is not very promising but which still reflect reality. Teachers know quite little about the professional careers in STEM and, worryingly, do not find it satisfactory that they could or would know where to find information and resources to guide their students or parents.

The patterns and themes researched and documented by means of the detailed study report can be used to decide to take new action in designing support services for teachers; improvement of training programs in action; understanding the results of students and their motivation towards STEM areas and professions.

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