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Stakeholder responses to core aspects of integrated STEM education: instrument development and pilot study

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ABSTRACT

The present paper reports on work undertaken within the frame of the STE(A)M IT project on integrated STEM education (Erasmus + Program; Grant agreement 612845-EPP-1-2019-1- BE-EPPKA3-PI-FORWARD). We will focus on a comprehensive review of grey and scientific literature published on integrated STEM and how this background desk research informed the development of an instrument designed to elicit stakeholder responses to core aspects of integrated STEM education. We have pilot tested the instrument to assess the validity and reliability of the scales it includes, and we present the results of this pilot study together with some implications for educational policy and stakeholder involvement.

SINTESI

L'articolo presenta una ricerca condotta nel quadro del progetto STE(A)M sull'educazione integrata alle STEM (Erasmus + Program; Grant agreement 612845-EPP-1-2019-1- BE-EPPKA3-PI-FORWARD). Sulla base di un'ampia revisione della letteratura grigia e scientifica si sviluppa uno strumento progettato per suscitare negli stakeholder risposte ad aspetti-chiave dell'educazione integrata alle STEM. Si presentano poi i risultati di uno studio pilota per testare attendibilità e affidabilità dello strumento. Infine, si discutono alcune implicazioni per le politiche educative e il coinvolgimento degli stakeholder.

KEYWORDS: integrated STEM education, instrument, pilot study, questionnaire, stakeholder involvement

PAROLE CHIAVE: educazione integrate STEM, strumenti, studio pilota, questionario, coinvolgimento stakeholder

Introduction[1]

Although Science, Technology, Engineering, and Mathematics (STEM) education should already denote some degree of interdisciplinarity of its subject domains, integration in authentic contexts proves to be highly challenging for primary and secondary teachers (Brown & Bogiages, 2019). At the same time, student interest in STEM learning seems to be declining in a period when demand for STEM skills and competencies increases in order to meet the related economic challenges (Hovardas et al., 2020). Furthermore, any initiatives undertaken to harness the benefits of interdisciplinarity and integration have been frequently hampered by a silo approach to STEM education and competing agendas between disciplines (Kelly & Knowles, 2016).

Integrated STEM education has been conceptualized as an effort to combine different STEM disciplines and other school subjects in an interdisciplinary fashion addressing real-world problems (Tasiopoulou et al., 2020). Apart from the challenges and contradictory background conditions already presented, an issue with integration is that innovation projects often fail to incorporate the necessary adaptations so that innovation can be taken up in pedagogical design and so that instruction in real classrooms and STEM teaching can be properly contextualized (Lowrie et al., 2017). A comprehensive stakeholder approach and interaction is urgently needed, in this direction, especially between teachers, Ministries of Education, and industry partners. Overall, it seems that the intentions are there but school practice and institutional reform are still lagging behind the current societal needs to promote interdisciplinarity and integration in STEM education.

In our effort to inform the development of an integrated STE(A)M education framework in the frame of the STE(A)M IT project (Erasmus + program; Grant agreement 612845-EPP-1-2019-1- BE-EPPKA3-PI-FORWARD), we formulated two research questions. First, what were the core aspects of integrated STEM education identified by previous research. Second, how stakeholders positioned themselves towards these core aspects. To address the first research question, we performed a desk research on scientific and grey literature on STEM education and presented our results in the form of an adapted Strengths, Weaknesses, Opportunities and Threats (SWOT) template. To address the second research question, we developed an instrument concentrating on these core aspects and we administered the instrument to stakeholders in a pilot study to validate its validity and reliability. We will present all methodological details of our approach in the

[1] The research presented in this article has been conducted in the frame of the STE(A)M IT project (Erasmus + program; Grant agreement 612845-EPP-1-2019-1- BE-EPPKA3-PI-FORWARD), which is coordinated by the European Schoolnet (EUN). Part of this research has been conducted in collaboration with following STE(A)M IT project partners: Istituto Nazionale di Documentazione, Innovazione e Ricerca Educativa (INDIRE), Università Telematica degli Studi IUL, Ministry Of Science And Education Of The Republic Of Croatia, Ministério da Educação – Direção-Geral da Educação (DGE) and University Of Cyprus. The content of the article is the sole responsibility of the authors and does not represent the opinion of the European Commission. The European Commission is not responsible for any use that might be made of information included in this article. We are thankful to all respondents who completed the instrument.

Methods section, the main findings in the Results section, and the main implications in the Discussion section.

1. Methods

1.1. Desk research

We performed a search of scientific articles, reviews and commentaries published in English between 2010 and 2019 in two different databases: ERIC (https://eric.ed.gov/) and SCOPUS (https://www.scopus.com/home.uri). The search keywords were "integrated STEM" or "STEM integration" or "STEM-integrated" in the article's title. After removing all articles not referring to the topic of our research (e.g., articles reporting on stem cell research), we arrived at a shortlist of 75 articles. Furthermore, we conducted a Google search for grey literature published in English between 2010 and 2019 using the keywords "STEM" and "integrated"; or "framework"; or "education"; or "recommendations"; or "teacher". We concentrated on strategic publications (e.g., reports; guidelines; statements; white papers; frameworks) published by Ministries of Education (including national STEM strategies), schools, and key industry partners in Europe, United States, and Australia. We also considered the following criteria for screening and selecting documents:

1. documents should involve more than on STEM discipline;
2. documents should report on more than a case study/school/teacher;
3. documents should include empirical data (qualitative, quantitative, mixed methods or meta-analysis);
4. data reported in documents should align with research focus and questions.

Following the above criteria, we added another 33 documents of grey literature in our shortlist (see Tasiopoulou et al., 2020 for a complete list of references). We content analysed the 108 documents in the shortlist by means of an adapted SWOT template, with stakeholders in separate columns (i.e., primary school teachers; secondary school teachers; Ministries of Education; industry partners) and rows depicting in-group aspects, which promoted or hindered integrated STEM uptake and implementation ("Strengths" and "Weaknesses", respectively), as well as inter-group aspects, again, promoting or hindering integrated STEM ("Opportunities" and "Threats", respectively).

The first and second author used each cell of the SWOT template as a separate code in a preliminary coding procedure. Following an elaboration on classification examples during this preliminary coding, new documents from the shortlist were processed, while the content of each cell of the template was reviewed and re-arranged, if necessary, for consistency. The final content of the SWOT template was concluded after repeated readings of the entire corpus and deleting overlaps by merging relevant references. Inter-rater reliability between the coders (first and second author) amounted to 80%. Mismatches between coders were classified following a final discussion between coders.

1.2. Instrument development and pilot study

Based on the desk research, we developed and pilot tested a questionnaire for gathering stakeholder responses (primary school teachers, secondary school teachers, Ministries of Education, and industry partners) to core aspects of integrated STEM education. The questionnaire included 47 five-point Likert scale items (completely disagree; disagree; neutral; agree; completely agree) organized around 11 scales (see Table 1, for the stakeholder groups where scales were administered, and Appendix, for a complete list of all items per scale): "Concept"; "Responsive instruction"; "Resources available"; "Pedagogical design"; "Funding"; "Professional development"; "Pre-service teacher education"; "Organizing principle"; "Main barriers to integrated STEM education"; "Change"; "Careers".

Scale	Number of items	Teachers	Ministries of Education	Industry partners
Concept	5	X		
Responsive instruction	4	X		
Resources available	5	X	X	
Pedagogical design	4	X	X	
Funding	4	X	X	X
Professional development	4	X	X	
Pre-service teacher education	4		X	
Organizing principle	4	X	X	X
Main barriers to integrated STEM education	5	X	X	
Change	4	X	X	X
Careers	4			X
Total	47	39	34	16

TABLE 1 - DISTRIBUTION OF QUESTIONNAIRE'S SCALES PER STAKEHOLDER GROUP[2]

2. Results

2.1. Desk research

Table 2 summarizes the main findings of our scientific and grey literature review. Stakeholders (primary teachers; secondary teachers; Ministries of Education; industry partners) are presented in different columns. The first two rows depict in-group aspects, which may either promote or hinder integrated STEM ("Strengths", and "Weaknesses", respectively). The next two rows portray inter-

[2] All items for each scale are presented in the Appendix.

group aspects which may, again, promote or hinder integrated STEM ("Opportunities", and "Threats", respectively). Reading a column from the top to the bottom one can have a comprehensive overview for each stakeholder group. Reading each row from the left to the right provides a thorough account of in-group and out-group aspects which can facilitate the uptake of integrated STEM ("Strengths" and "Opportunities", respectively) or create barriers to integration ("Weaknesses", and "Threats", respectively).

	Primary teachers	Secondary teachers	Ministries of Education	Industry partners
Strengths (in-group aspects, which promote integrated STEM)	Collaborative pedagogical design (Margot & Kettler, 2019)	Collaborative pedagogical design (Kelly & Knowles, 2016; Thibaut et al., 2018)	Recent reforms favour integration (Kelly & Knowles, 2016; National STEM Strategies, Actions and Initiatives in Spain, 2017)	Integrated STEM develops knowledge and skills needed in the workforce (Crossing the Chasm to Mainstream STEM Education, 2019)
Weaknesses (in-group aspects, which hinder integrated STEM)	Lack of knowledge and skills (Galadima et al., 2019; Guzey et al., 2016a); teachers locked into a “localized” pedagogical design overview (McFadden & Roehrig, 2017)	Lack of knowledge and skills (Kelly & Knowles, 2016) and time constraints (Brown & Bogiages, 2019); current practice hinders integration (Thibaut et al., 2018)	Engineering not often included in integration initiatives (Honey et al., 2014; Susilo et al., 2016); silo approach to STEM (Kelly & Knowles, 2016)	Crucial information about STEM careers is lacking (Lowrie et al., 2017)
Opportunities (inter-group aspects, which promote integrated STEM)	Resources (National STEM Strategies, Actions and Initiatives in France, 2017) and professional development programs (National STEM strategies, Actions and initiatives in Slovakia, 2017) available for integrated STEM	Professional development programs available for integrated STEM (Brown & Bogiages, 2019; Nadelson et al., 2012; Roehrig et al., 2012; Thibaut et al., 2018, 2019)	Engineering design (Burrows et al., 2018; Johns & Mentzer, 2016); project-based learning (Mustafa et al., 2016; Siew & Ambo, 2018); educational robotics (Chen & Chang, 2018; Susilo et al., 2016).	Developing and funding STEM learning programs, mainly in partnerships with other stakeholders (National STEM Strategies, Actions and Initiatives in Hungary, 2017)
Threats (inter-group aspects, which hinder integrated STEM)	Most curriculum and assessment requirements stand in sharp contrast to integrated STEM (Guzey et al., 2016a; Sinatra et al., 2018)	Creating a supportive school culture for integrated STEM is costly and time-consuming (Stohlmann et al., 2012; Thibaut et al., 2018).	Design challenges inherent to integration, e.g., integration can only follow after the establishment of each STEM discipline (Guzey et al., 2016b; Thibaut et al., 2018)	Stakeholder initiatives not systematically connected to the curriculum but usually aligned to the main function of the provider (Lowrie et al., 2017)

TABLE 2 - STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS (SWOT) TEMPLATE FOR INTEGRATED STEM

Collaborative pedagogical design featured as a main strength for both primary and secondary teachers in advancing integrated STEM. However, there are still substantial weaknesses in terms of necessary knowledge and skills among teachers in both educational levels. This locks primary teachers into a "localized" pedagogical design overview, preventing them from developing the bridges necessary for integration. On several occasions it has been reported that current practice prevents secondary teachers from taking up integrated STEM. Specifically, Thibaut et al. (2018) found that years of teaching were negatively correlated with attitudes toward teaching integrated STEM. Furthermore, Kelly and Knowles (2016) highlighted that integrated STEM necessitates a community of practice approach, since it would demand networking with experts and opening classroom to peers and other professionals, which is deemed as too demanding and challenging by teachers.

Stakeholder interaction for integrated STEM is supported by available resources and professional development programs (Table 2, "Opportunities" for primary and secondary teachers). At the same time, however, several institutional constraints seem to prevent a wider uptake of integrated STEM, such as curriculum and assessment requirements in primary education (Table 2, "Threats" for primary teachers) and cost and time constraints in secondary education (Table 2, "Threats" for secondary teachers).

Recent reforms undertaken by several Ministries of Education have favoured STEM integration (Table 2, "Strengths" for Ministries of Education). However, a main barrier for integrated STEM still persisting in many national curricula is the silo approach to STEM education with a segregated and discipline-based structure. Moreover, some STEM disciplines, foremost engineering, are not often incorporated in integration initiatives (Table 2, "Weaknesses" for Ministries of Education). Indeed, engineering design together with project-based learning and educational robotics have been underlined as focal learning scenarios/domains for promoting integrated STEM (Table 2, "Opportunities" for Ministries of Education). In addition, there are quite a few design challenges inherent to integration, for example the perspective that integration can only succeed when the establishment of each STEM discipline has been secured (Table 2, "Threats" for Ministries of Education).

With regard to industry partners, they are especially interested in the necessary knowledge and skills to be developed in the workforce (Table 2, "Strengths" for industry partners). At the same time, however, crucial information about STEM careers is lacking, not allowing for a fully-fledged tracking of job and employment trajectories with a pronounced integration component (Table 2, "Weaknesses" for industry partners). Although many industry partners are currently involved in developing and funding STEM learning programs, mainly in partnerships with other stakeholders (Table 2, "Opportunities" for industry partners), these initiatives do not systematically connect to the curriculum but are mainly focused on the main function of the provider (Table 2, "Threats" for industry partners).

2.2. Instrument development and pilot study

Sample characteristics

A total of 71 respondents completed the online questionnaire. We excluded from data analysis respondents who worked in a country outside Europe (4 respondents), and we also deleted another 2 respondents who represented industry partners. This later deletion was necessary since we had only these 2 respondents from the stakeholder group of industry partners, which was not enough for comparisons between stakeholder groups. The final ample included 65 respondents: 9 represented Ministries of Education, 12 were teachers in primary education, while 44 were teachers in secondary education. Teachers had, overall, a median of 4 years of teaching experience (max = 6 years; min = 1 year) and came from 21 different countries. Before completing the questionnaire, all respondents provided their consent to a Data Protection Disclaimer Information on data collection and processing.

Validity and reliability analyses

Validity and reliability analyses were conducted for all scales, apart from "Pre-service teacher education" and "Careers", for which we did not receive enough responses for running these analyses. With regard to validity analysis, we conducted a factor analysis (extraction: Principal component; rotation: Varimax; Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.87; Chi-Square for the Bartlett's Test of Sphericity = 6687.22, $p < 0.001$), which revealed that all items loaded on two factors which together explained 91.69% of total variance in the data. All items of the scales "Resources available", "Pedagogical design", "Funding", "Professional development", "Organizing principle", "Main barriers to integrated STEM "education", and "Change" loaded on factor 1, while all items of the scales "Concept" and "Responsive instruction" loaded on factor 2. This allocation of items on factors revealed that items maintained their scale-reference, when the responses of the sample were accounted for, and therefore, our instrument was valid. Further, factor 2 ("Concept"; "Responsive instruction") seems to reflect the basics of teacher preparation for integrated STEM, whereas the rest of the scales allocated on factor 1 address institutional support needed and stakeholder preparedness to promote integrated STEM.

With regard to reliability analysis, most scales revealed Cronbach's alpha indices over 0.70 (Cronbach's alpha for: "Concept" = 0.80; "Responsive instruction" = 0.84; "Resources available" = 0.89; "Professional development" = 0.82; "Organizing principle" = 0.82; "Main barriers to integrated STEM education" = 0.86), reflecting satisfactory reliability, while three scales revealed marginal reliability (Cronbach's alpha for: "Pedagogical design" = 0.61; "Funding" = 0.66; "Change" = 0.56).

Responses of stakeholder groups to questionnaire items

Non-parametric statistical tests (Kruskal-Wallis and Mann-Whitney tests) revealed no statistically significant differences between stakeholder groups across all scales, after the implementation of the Bonferroni correction for multiple comparisons. In addition, there were no statistically significant trends related to years of teaching experience. However, there were some major trends in data. Stakeholder groups presented a consistent pattern across all scales, with teachers in primary education having the relatively highest average values for all items, followed by teachers in secondary education, and then, representatives of Ministries of Education (see Tables 3-11).

Starting with “Concept” (Table 3) and “Responsive instruction” (Table 4), primary school teachers reported a better comprehension of integrated STEM (“Concept”) and they were, according to their self-reports, much more competent in designing and implementing integrated STEM lessons (“Responsive instruction”) as compared to secondary school teachers. Since these two scales were allocated on factor 2, our findings indicate that primary school teachers appeared more prepared than secondary school teachers for moving towards the direction of integrated STEM. We need to highlight that these two scales were not distributed to representatives of Ministries of Education (see also Table 1).

An analogous trend was revealed for scales which loaded on factor 1, and which referred to institutional support needed and stakeholder preparedness to promote integrated STEM. Primary school teachers were more optimistic on the availability of quality educational resources (“Resources available”, Table 5), teacher and stakeholder collaboration for facilitating pedagogical design for integrated STEM (“Pedagogical design”, Table 6), availability of funding opportunities (“Funding”, Table 7) and professional development programs for integrated STEM (“Professional development”, Table 8). A further indication of the optimism of primary school teachers is that they believed that several options can serve as organizing principles of integrated STEM (“Organizing principle”, Table 9). This optimism was accompanied by endorsement of all multifarious adaptation and change needed for fostering integrated STEM (“Main barriers to integrated STEM education”, Table 10; “Change”, Table 11).

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
I have a clear understanding of what integrated STEM education is	-	3.92	3.14	2.85
I have heard colleagues talking about integrated STEM education	-	3.25	2.82	2.51
I have talked with colleagues about integrated STEM education	-	3.92	3.09	2.82
I know how to develop an engineering design task for my students	-	3.33	2.75	2.48
I can employ teaching approaches that foster integrated STEM education	-	3.67	2.91	2.65

TABLE 3 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "CONCEPT"[3]

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
I feel competent to design an integrated STEM lesson plan	-	3.67	2.89	2.63
It is easier for me to design an integrated STEM lesson plan based on a given example	-	3.58	2.98	2.68
I feel competent to orchestrate an integrated STEM lesson	-	3.58	2.80	2.55
I can offer support to my students when they enact an integrated STEM learning task	-	3.75	2.93	2.68

TABLE 4 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "RESPONSIVE INSTRUCTION"

[3] Items for the scale "Concept" and "Responsive instruction" were not included in the instrument for Ministries of Education; average values given along a 5-point Likert scale (min = 1; max = 5).

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
There are enough resources and material available for integrated STEM education	1.22	3.25	2.57	2.51
The resources and material available for integrated STEM education are useful	1.44	3.25	2.84	2.72
The resources and material available for integrated STEM education can be easily implemented in everyday school practice	1.22	3.00	2.59	2.48
The resources and material available for integrated STEM education fit with the national curriculum	1.56	2.92	2.39	2.37
The resources and material available for integrated STEM education are interesting for students	1.78	3.33	2.95	2.86

TABLE 5 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "RESOURCES AVAILABLE"[4]

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
Many teachers are willing to collaborate with their colleagues in designing lesson plans for integrated STEM education	1.44	3.08	2.39	2.38
Collaboration between teachers can deliver more interesting resources and material for integrated STEM education than are currently available	1.89	3.83	2.91	2.94
Many teachers are willing to collaborate with stakeholders in designing lesson plans for integrated STEM education	1.56	3.25	2.34	2.40
Collaboration between stakeholders can deliver more interesting resources and material for integrated STEM education than are currently available	1.89	3.67	2.93	2.92

TABLE 6 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "PEDAGOGICAL DESIGN"

[4] Average values for "Resources available", "Pedagogical design", "Funding", "Professional development", "Organizing principle", "Main barriers to integrated STEM education" and "Change" given along a 5-point Likert scale (min = 1; max = 5).

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
Industry partners should allocate more funding to integrated STEM education	1.89	3.67	2.95	2.94
Ministries of Education in Europe should allocate more funding to integrated STEM education	1.78	3.83	3.00	2.98
There are many opportunities to support integrated STEM education by funding at the national level	1.11	2.50	2.43	2.26
There are many opportunities to support integrated STEM education by funding at the European level	1.56	3.33	2.80	2.72

TABLE 7 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "FUNDING"

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
Professional development programs offer enough opportunities for engaging teachers in integrated STEM education	1.22	3.33	2.45	2.45
Professional development programs promote collaboration among teachers for designing lesson plans in integrated STEM education	1.33	3.50	2.52	2.54
Professional development programs promote collaboration among stakeholders for designing lesson plans in integrated STEM education	1.33	3.25	2.30	2.34
Professional development programs focus much more on each one of the STEM disciplines than on their integration	2.11	3.00	2.77	2.72

TABLE 8 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "PROFESSIONAL DEVELOPMENT"

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
Engineering design education can be used as an organizing principle in integrated STEM education	1.89	3.42	2.86	2.83
Project-based learning can be used as an organizing principle in integrated STEM education	2.11	3.75	3.09	3.08
Robotics can be used as an organizing principle in integrated STEM education	1.67	3.75	2.91	2.89
Each STEM discipline can serve as an organizing principle for integrated STEM education	1.67	3.67	2.93	2.89

TABLE 9 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "ORGANIZING PRINCIPLE"

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
Average school culture and environment does not favour integrated STEM education	1.89	3.25	2.68	2.68
Everyday school practice does not favour integrated STEM education	1.89	3.17	2.64	2.63
Average teacher skills do not favour integrated STEM education	2.00	3.00	2.68	2.65
Current curriculum requirements do not favour integrated STEM education	1.67	3.50	2.80	2.77
Current assessment methodologies for students do not favour integrated STEM education	1.89	3.50	2.86	2.85

TABLE 10 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "MAIN BARRIERS TO INTEGRATED STEM EDUCATION"

Items	Ministries of Education (n=9)	Teachers in primary education (n=12)	Teachers in secondary education (n=44)	Total sample (n=65)
All stakeholders agree that reform is needed to foster integrated STEM education	1.89	3.67	2.75	2.80
Drastic institutional change is needed for integrated STEM education	2.00	3.58	3.02	2.98
A national strategy for integrated STEM education is missing	1.89	3.83	2.95	2.97
Integrated STEM education should be a priority for Europe	2.00	3.83	3.18	3.14

TABLE 11 - AVERAGE RESPONSES OF STAKEHOLDERS FOR "CHANGE"

3. Discussion

3.1. Core aspects of integrated STEM education

The literature research we conducted indicated that there are significant in-group aspects which support stakeholders' intention to advance integrated STEM, for example, collaborative design initiatives by primary and secondary teachers, reforms attempted by Ministries of Education and the development of necessary knowledge and skills in the workforce for industry partners. However, these intentions seem to be compromised by substantial in-group weaknesses like inadequate knowledge and skills of teachers to effectively support integrated STEM teaching, segregation of STEM disciplines which still prevails in most curricula and lack of important information on STEM careers. Professional development programs may unite and empower stakeholders in taking up integrated STEM, especially when they focus on engineering design, project-based learning or educational robotics. To build on these positive inter-group aspects, stakeholders need to overcome several barriers in current school instructional and institutional practice, like curriculum and assessment requirements which are not compatible with integrated STEM education and time constraints which do not allow for concerted investment of resources on integration.

3.2. Pilot analysis of the instrument

Data analysis showed that the questionnaire includes six scales of satisfactory reliability ("Concept"; "Responsive instruction"; "Resources available"; "Professional development"; "Organizing principle"; "Main barriers to integrated STEM education") and another three of marginal reliability ("Pedagogical design"; "Funding"; "Change"). All scales comprised a valid instrument, altogether, to be used for assessing stakeholder positions. The instrument can have various uses, for instance, in evaluating integrated STEM initiatives, as well as in pre-post test measurements of stakeholder positions.

A possible implication and limitation of our approach may have been the disproportional frequency of stakeholder groups in our sample. Larger numbers of respondents, distributed more evenly across stakeholder groups, may have substantiated our findings better. However, we need to underline that the current sample represented 21 different countries in Europe, providing a notable geographical coverage. Any future use of the questionnaire will add to the robustness of the findings outlined in this paper.

With regard to the basic aspects of teacher preparation for implementing integrated STEM (scales "Concept" and "Responsive instruction", which loaded on factor 2), primary school teachers appeared more prepared than secondary school teachers to take up integrated STEM. It can be that the primary school curriculum may be much more compatible with integrated STEM than the secondary school curriculum, which has the characteristic of a compartmentalization of STEM domains, with many implications for learning and instruction, everyday school practice, and teacher attitudes.

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Appendix: Questionnaire items

1. Concept

- I have a clear understanding of what integrated STEM education is.
- I have heard colleagues talking about integrated STEM education.
- I have talked with colleagues about integrated STEM education.
- I know how to develop an engineering design task for my students.
- I can employ teaching approaches that foster integrated STEM education.

2. Responsive Instruction

- I feel competent to design an integrated STEM lesson plan.
- It is easier for me to design an integrated STEM lesson plan based on a given example.
- I feel competent to orchestrate an integrated STEM lesson.
- I can offer support to my students when they enact an integrated STEM learning task.

3. Resources available

- There are enough resources and material available for integrated STEM education.
- The resources and material available for integrated STEM education are useful.
- The resources and material available for integrated STEM education can be easily implemented in everyday school practice.
- The resources and material available for integrated STEM education fit with the national curriculum.
- The resources and material available for integrated STEM education are interesting for students.

4. Pedagogical Design

- Many teachers are willing to collaborate with their colleagues in designing lesson plans for integrated STEM education.
- Collaboration between teachers can deliver more interesting resources and material for integrated STEM education than are currently available.
- Many teachers are willing to collaborate with stakeholders in designing lesson plans for integrated STEM education.
- Collaboration between stakeholders can deliver more interesting resources and material for integrated STEM education than are currently available.

5. Funding

- Industry partners should allocate more funding to integrated STEM education.
- Ministries of Education in Europe should allocate more funding to integrated STEM education.
- There are many opportunities to support integrated STEM education by funding at the national level.
- There are many opportunities to support integrated STEM education by funding at the European level.

6. Professional development

- Professional development programs offer enough opportunities for engaging teachers in integrated STEM education.
- Professional development programs promote collaboration among teachers for designing lesson plans in integrated STEM education.
- Professional development programs promote collaboration among stakeholders for designing lesson plans in integrated STEM education.
- Professional development programs focus much more on each one of the STEM disciplines than on their integration.

7. Pre-service teacher education

- Pre-service teacher education programs offer enough opportunities for engaging teachers in integrated STEM education.
- Pre-service teacher education programs promote collaboration among teachers for designing lesson plans in integrated STEM education.
- Pre-service teacher education programs promote collaboration among stakeholders for designing lesson plans in integrated STEM education.
- Pre-service teacher education programs focus much more on each one of the STEM disciplines than on their integration.

8. Organizing principle

- Engineering design education can be used as an organizing principle in integrated STEM education.
- Project-based learning can be used as an organizing principle in integrated STEM education.
- Robotics can be used as an organizing principle in integrated STEM education.
- Each STEM discipline can serve as an organizing principle for integrated STEM education.

9. Main barriers to integrated STEM education

- Average school culture and environment does not favour integrated STEM education.
- Everyday school practice does not favour integrated STEM education.
- Average teacher skills do not favour integrated STEM education.
- Current curriculum requirements do not favour integrated STEM education.
- Current assessment methodologies for students do not favour integrated STEM education.

10. Change

- All stakeholders agree that reform is needed to foster integrated STEM education.
- Drastic institutional change is needed for integrated STEM education.
- A national strategy for integrated STEM education is missing.
- Integrated STEM education should be a priority for Europe.

11. Careers

- An integrated STEM approach is important for STEM careers.
- Thinking STEM subjects together helps solve current challenges in the industry.
- The future workforce in my sector requires interdisciplinary thinking.
- Teaching STEM subjects in an integrated way helps students develop skills needed in the industry.