Fostering European Students' STEM Vocational Choices

Irina Kudenko, Cristina Simarro, and Roser Pintó

Introduction

Young people's competence in Science, Technology, Engineering and Mathematics (STEM) education and their interest in related careers have consistently been a major concern in Europe. The last assessment of STEM competencies (EC 2013) and employability skills (EC 2015a) confirmed the proliferation of negative trends and predicted the internal supply of STEM-related professionals in the next decade to fall short of the EU labour market needs. These political concerns fuel academic research on students' interest in STEM learning, career aspirations and choices, particularly on factors that shape students' views and influence their actions related to STEM education and careers (DeWitt et al. 2014).

Research identifies four basic groups of interrelated factors affecting student career choices in STEM (ECB-InGenious 2011a). First, good subject knowledge, competence in STEM disciplines and students' engagement in learning (factor group A) are commonly recognised as essential prerequisites to positive attitudes to STEM learning and careers. However, on their own these factors are often not enough to stimulate career aspirations of students (The Royal Society 2004), and researchers point to the importance of students' knowledge of STEM-related careers (group B) and their personal beliefs, values and self-perceived abilities to accomplish education and career-related tasks (group C) (Fouad 2007). Finally, social views and popular stereotypes of STEM industries and careers (group D) are also acknowledged as influential, especially with regard to a damaging role of negative stereotypes (Sjøberg and Schreiner 2010).

I. Kudenko
National STEM Learning Centre, York, UK

C. Simarro (✉) • R. Pintó
Universitat Autònoma de Barcelona, Barcelona, Spain
e-mail: cristina.simarro.rodriguez@uab.cat

K. Hahl et al. (eds.), *Cognitive and Affective Aspects in Science Education Research*, Contributions from Science Education Research 3,
DOI 10.1007/978-3-319-58685-4_24

Applying this framework to the analysis of educational initiatives and policies helps identify which groups of factors these interventions try to influence and how they do it. Here, the cooperation between education and social partners (such as representatives of STEM industries) is justifiably acknowledged as a potentially good approach for updating, enriching and contextualising science education, as well as providing valuable expertise and resources (see Wright 1990 for a comprehensive account of the origins of these relationships). There is evidence suggesting that STEM employers' involvement in education creates a multidimensional positive impact on students, affecting their academic outcomes, work and personal skills, career awareness and preferences (Burge et al. 2012). Specifically, it has been argued that a closer cooperation of school with STEM-related industries could help in raising students' awareness of STEM careers, bringing the world of work closer to education (ERT 2009). However, many questions about the process, forms and effectiveness of such cooperation remain under-researched (Andrée and Hansson 2015; Mann 2012).

There have been some advances in researching limitations and gaps in school-industry partnerships, which, it has been argued, can seriously jeopardise the effectiveness and actual impact of such arrangements (BSCR 2011). Most of these partnerships have a voluntary nature (Marriott and Goyder 2009), which can be positive in terms of flexibility and innovation, but may also entail blurred objectives and lack of commitment and sufficient expertise in the education field. Evidence suggests that this lack of clarity about the main objectives of employer-school interactions as well as a lack of comprehensive evaluation may have a negative impact on the success of such programmes (Burge et al. 2012; NCSR 2008). Additionally, most of the existing school-industry partnerships are isolated and short term.

It is not surprising, therefore, that those in charge of linking industries with education feel concerned by the lack of clear guidance on how to make school-industry collaboration as worthwhile as it should be (CBI 2012). This, however, requires a good understanding of what makes collaborations effective in promoting STEM education and careers and how to maximise their impact on students' aspirations.

There is an equal need to study and learn from the existing initiatives implemented within the framework of school-industry partnership. This research was set up to address some of these concerns and, more specifically, intended to answer the following questions:

- What are the common characteristics of European school-industry partnerships in STEM education, and how well do they match theories related to STEM aspirations promotion?
- What are the barriers and gaps in school-industry collaboration across Europe, and what could be done to resolve them and, consequently, to increase their effectiveness?
- What can we learn from evaluating the impact (on teachers' engagement and students' STEM careers aspirations) of school-industry collaborations implemented under the auspices of a common Europe-wide initiative?

Context and Methodology

The data for this paper comes from the European project ECB-inGenious, a multi-stakeholder FP7 initiative which involved over 40 partner organisations representing European industry, policy makers and STEM educators. The overall objective of the project was to foster young people's aspirations towards STEM careers. To this aim, we facilitated schools' engagement with STEM education activities, resources and events designed and supported by industry partners. The project ran for 3 years (2011–2014) engaging over 1500 classrooms across Europe. Around 160 schools in each project year received additional support, professional development and resources from industry partners in exchange for their participation in rigorous evaluation of project activities. After each project year, these 'pilot schools' were able to reapply and remain in the project.

The project provided a stable and sustainable platform for an ongoing dialogue between schools, industry experts and educational specialists. Specifically, teachers had numerous opportunities to engage in professional learning and networking during face-to-face activities (three summer schools, three teacher academies and nine teacher workshops) and online (through webinars and chats with industry experts, themed professional communities and teacher forums). As the project developed, they also gained access to an online database of educational resources developed/supported by industry partners from various EU regions.

ECB-inGenious had multiple research and evaluation activities focusing on the role of school-industry partnerships in developing, promoting and supporting STEM enrichment activities in schools across Europe. Seeking a broader perspective on the research questions, we combined quantitative and qualitative research methods (Teddlie and Tashakkori 2009). It commenced with the examination of existing school-industry partnerships in Europe, reviewing their aims, methodologies and educational policies and sampling their STEM enrichment activities. This examination was based on the responses collected from STEM industries and industry networks to an online survey consisting of both open and closed-ended questions (ECB-InGenious 2011a).

A total of 153 different local, regional, national and European STEM enrichment initiatives developed by business and industry for schools were gathered from 17 countries. Due to a varying quality of information provided, only 79 of them, covering 14 EU and EU partner countries, were included in the next stage of detailed quantitative and qualitative examination (Fig. 1). We used descriptive statistical methodology to analyse closed-ended responses, while open-ended questions, containing detailed descriptions of initiatives, were analysed using a theory-driven content analysis (Namey et al. 2008) and categorised by two researchers working independently. The first researcher classified school-industry initiatives by types of involved activity (e.g. talk) and identified which factors known to influence students' career aspirations (A, B, C and D) were addressed by each initiative. The process was independently repeated by the second researcher, and then their results were compared and validated by computing Cohen's kappa (0.80 and 0.82, respectively), a standard measure for

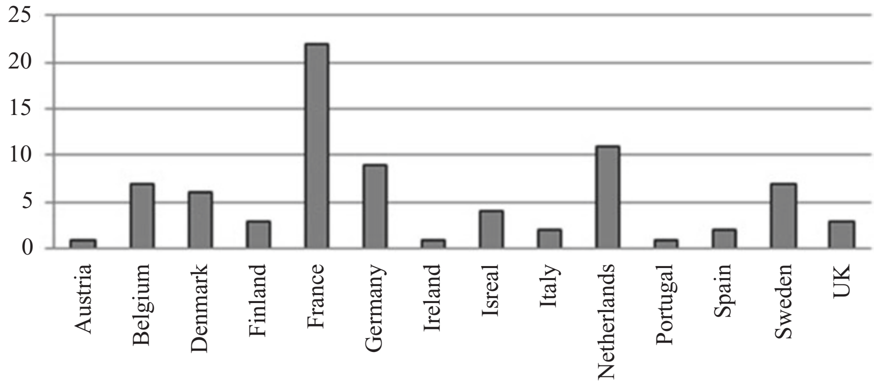

Fig. 1 Country origin and number of practices included in the analysis

inter-coder reliability (Neuman 1997). To double-check that no important information was missing from excluding the incomplete datasets, we applied the proposed categorisation to all collected initiatives ($n = 153$). This exercise confirmed the robustness and validity of the instrument and showed that the subsample of 79 initiatives, despite a varying number of activities sampled from each country, was largely representative of all collected activities.

In parallel, the project carried out a wider examination of school-industry collaboration in STEM education, seeking to identify educational and business needs, and existing gaps and various barriers to school-industry partnerships. We organised 15 national and one European workshop consultations with various stakeholders (teachers, industry representatives, policy makers, STEM education experts and providers of professional development and resources). The outputs of these workshops were summarised in corresponding national 'needs analysis' reports and a European white paper on the state of school-industry collaboration in STEM education in Europe (ECB-InGenious 2013). Again, content analysis was used, this time based on data itself.

Finally, the project focused on testing existing and newly created STEM enrichment activities for schools and on assessing their impact on teaching of STEM disciplines, student views and career aspirations. In total, 35 school-industry initiatives were prepared for 'testing' and subjected to rigorous evaluation: 14 were available in year one of the project, 24 in the second and 29 in the final year. All of them were initially available in English and at least one more European language, but, with time, most of the activities were translated into five or more of the native languages of project participants. Schools participating in evaluation were free to choose any of these activities but were expected to implement at least three annually.

Student and teacher online questionnaires were administered before, during and after each project year (Table 1) (ECB-InGenious 2011b, 2014b).

All questionnaires mainly consisted of close-ended multi-choice nominal and scaled questions. There were both single-choice and multi-choice nominal questions, while a typical scaled question measured responses on a four-point Likert-type

Table 1 Evaluation questionnaires and the number of responses in each project year and overall

	Questionnaires	N° of responses			
		Year 1	Year 2	Year 3	Overall
Teachers	School baseline information (PA1)	168	170	179	517
	Teacher baseline views and expectations (PA2)	127	175	176	487
	Intended use of a project activity (NA1)	254	444	582	1280
	Activity evaluation and feedback (NA2)	206	387	524	1117
	End-of-the-year views and feedback (PO1)	104	118	192	414
Students	Baseline views (PA3)	3260	5816	5347	14,423
	Activity evaluation and feedback (NA3)	3198	6650	9811	19,659
	End-of-the-year views and feedback (PO2)	N/A	2952	5071	8023

scale: 'strongly agree', 'agree', 'disagree' and 'strongly disagree'. For reporting purposes this rating scale was often converted into an 'agree-disagree' dichotomy. When necessary, the four-point scale was expanded to include a fifth option, which accounted for either no opinion ('don't know') or inappropriateness of a question ('not applicable'). These answers were discarded when converting to a dichotomous scale. Occasionally we required a more sensitive instrument to measure a range of participants' views, so a ten-point semantic differential scale (Osgood 1964) was used. For example, to measure students' perception of project activities in comparison to their experience of everyday classroom work, we employed a scale that ranged from one ('much worse') to ten ('much better'). Then we used standard statistical methods to generate descriptive and inferential statistics and analyse quantitative variables and their relationships.

Finally, to capture qualitative, in-depth information and to give more opportunities for participants to respond in detail, a few open-response questions were added to each of the surveys. Answers to these questions were mainly used for illustrative purposes, but we also applied basic content analysis techniques to explore their range and prevalence of certain narratives.

At the start of each project year, we collected baseline data on schools, teachers and students participating in testing of the project activities. We asked about schools' history of collaboration with STEM industries, views on STEM learning, attitudes to STEM industries and student career inclinations. At the end of each project year, teachers and students completed final questionnaires answering similar attitudinal questions and providing feedback on the activities and their impact. In addition, teachers also filled in two special forms per each implemented activity: one form immediately before the activity to capture details of the intended use and one immediately after the trial to gather implementation details and evaluation feedback. A quick and simple survey was used to gather student reflections on the practice.

All questionnaires were translated into 15 European languages, which covered most of the project participants' countries (those not covered had to use an English version of the questionnaire). Due to various constrains, we could only collect student responses from a sample of benefitting students, which were nominated by

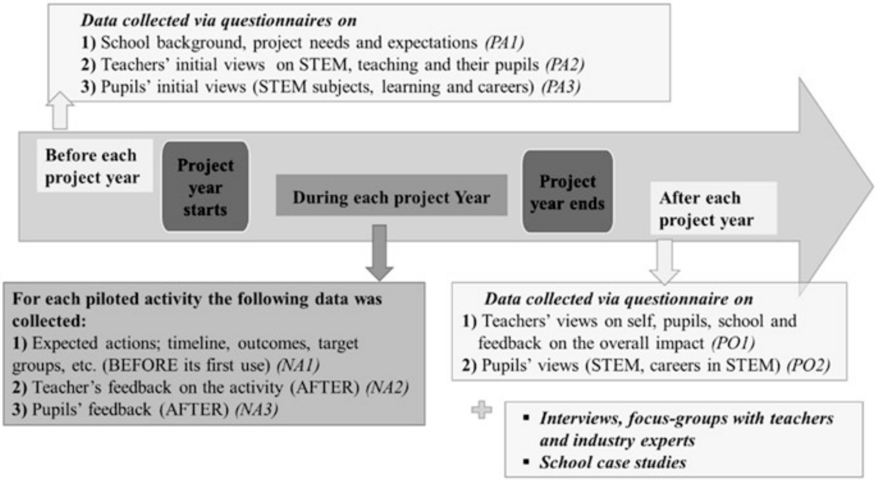

Fig. 2 Project evaluation timeline and instruments

their teachers. However, teachers had clear guidelines requesting that the same students complete every project questionnaire.

We also collected extensive qualitative data using case studies written by teachers, focus groups and interviews with teachers, students and head teachers, as well as other data sources. The evaluation process and instruments are detailed in Fig. 2.

Although data collection and analysis had certain methodological limitations and challenges (e.g. duplicate entries), they were mitigated by the volume, geographical spread and historical consistency of the collected responses (Ross 1992). We also triangulated (Patton 1999) student data with teachers' views on changes in students' perceptions of STEM, which showed a consistent picture of improving learning and career aspirations.

Results and Discussion

Common Characteristics of Sampled School-Industry Partnerships

The 79 educational initiatives sampled in the project confirmed the existence of gaps and limitations in school-industry collaboration identified in the literature. For instance, although some of the initiatives were applicable to more than one age group, the overwhelming majority of them were targeting secondary school students (90%) (Fig. 3).

The duration of the analysed initiatives is another characteristic worth a special note. Nearly two thirds of the reviewed initiatives were short-term/one-off activities

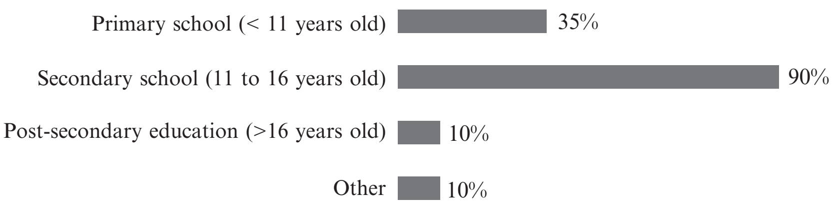

Fig. 3 Distribution of school-industry initiatives sampled in the project (N = 79) by the age of students they targeted (some initiatives were applicable to more than one age group)

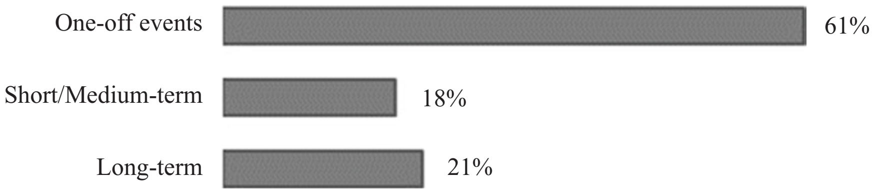

Fig. 4 Distribution of school-industry initiatives sampled in the project (N = 77) by the time scale of their application (Note: initiatives aimed only at teachers are not included)

(64%), whereas long-term activities, i.e. those carried out during 1 month or more and which, consequently, would have more opportunities for students to work in-depth and jointly with STEM professionals, represented a 21% of the gathered activities (Fig. 4).

Most of the existing practices were focused on the production of learning resources for STEM subjects (46%), with the involvement of industries being minimal (mostly reduced to funding and project management). Activities with a bigger involvement of industry representatives in STEM education, e.g. industry visits/talks or STEM professionals' involvement in school projects, were less frequent (24% and 15% correspondingly). Worryingly, only 6% of initiatives included teacher training and professional development (Fig. 5).

Of special interest to our research was the link between the reviewed initiatives and the four groups of factors, identified in the literature as influencing student aspirations towards STEM careers. This analysis has shown that most initiatives were focused on supporting STEM curriculum learning (factor group A, 62%), giving less support for career information (factor B, 41%) and often neglecting personal and social attitudinal issues (factors C and D, 25%) (Fig. 6).

Finally, the study also confirmed that impact evaluation, especially with regard to pupil outcomes, remains a 'missing part' in most of the cases: only 27% of the initiatives reported some sort of impact evaluation, and, even then, most of the evaluation activities were reduced to counting participants and conducting satisfaction surveys.

Overall, the analysis of sampled initiatives identified the following gaps and inefficiencies in school-industry partnerships. First, it showed the imbalance in addressing the factors that influence career aspirations of students. While research

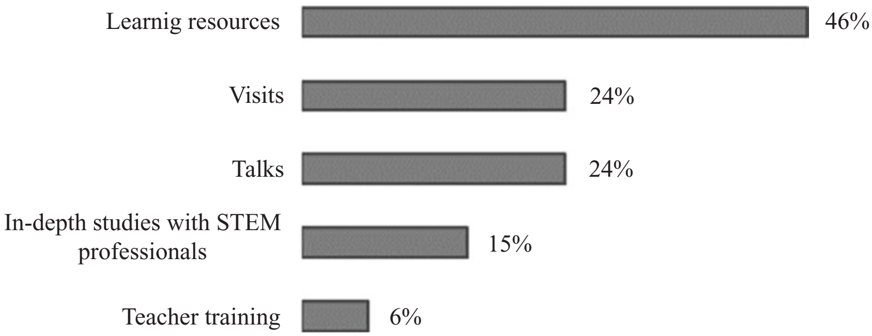

Fig. 5 School-industry initiatives by the type of involved activities (one school-industry initiative could include a few activity types (total sum is greater than 100%))

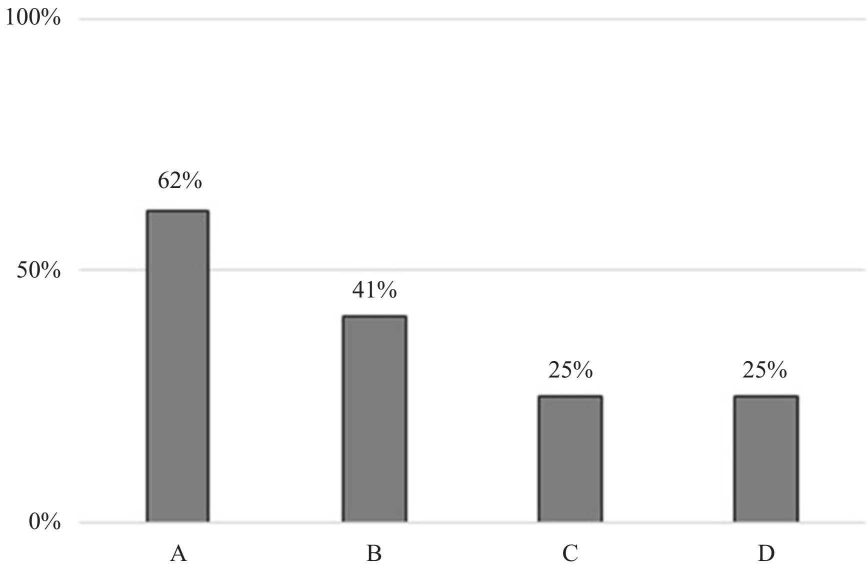

Fig. 6 School-industry initiatives by their focus on the group of factors, which influence students' career motivation. Most activities address more than one factor (total sum is greater than 100%)

evidence shows that effective initiatives have to address all (or most) factor groups outlined previously (factors A, B, C, D), in reality, career information (B) and psychological (C) and social (D) factors are often neglected. Secondly, it confirmed that industrialists prefer to design their initiatives for secondary school students. This bias in selecting the target audience also contradicts the research evidence, which shows that by the age of 14 students' attitudes and interests in STEM learning and careers are largely formed (Archer 2013).

Table 2 Obstacles and barriers identified by stakeholder representatives as hindering school-industry collaborations

Barriers		Type of barrier	
Lack of resources (economic/human/time)	23%	Structural	35%
Lack of support	10%		
Geographical closeness between schools and companies	2%		
Goals of the collaboration	18%	Motivational	33%
Lack of partners interested in collaborating	9%		
Lack of continuity/commitment between partners	6%		
Communication between partners	13%	Procedural	17%
Existing regulations	4%		
Different realities of the worlds of industry and education	13%	Cultural	16%
Matching of schedules	2%		
Negative stereotypes of industry in school	1%		

Many STEM industries do not engage with schools on continuous basis and tend to offer one-off events and short and simple activities. This is despite a clear warning coming from academic research, which demonstrates that one-off interventions are significantly less likely to have a long-term impact (Savickas et al. 2009). Finally, absence of considerations for impact evaluation undermines their potential for self-improvement, which further reduces their effectiveness in raising student career aspirations (Burge et al. 2012; Marriott and Goyder 2009; NCSR 2008).

Current Barriers and Gaps in School-Industry Collaboration

The 'needs analysis' data collected within the project proved very useful in interpreting and understanding the origin of some of the gaps described in a previous section. Specifically, national reports (ECB-InGenious 2013, 2014a) collecting the opinion of representatives from the educational, industrial and political sectors pointed to the existence of the following four major groups of obstacles:

1. Structural obstacles (related to partners' limited availability of resources, support and infrastructure).
2. Motivational obstacles (related to disjointed and even contradictory interests, goals and motivations of the parts involved).
3. Procedural obstacles, (related to the way school-industry links are managed, e.g. lack of stable organisational and networking structures).
4. Cultural obstacles (related to different ways in which school and industry approach STEM education as well as mistrust/misunderstanding/lack of knowledge of the aims and cultural settings of the other side in a partnership). Table 2 shows these types of barriers and the frequency of their appearance in the reports.

As we can see from Table 2, most of the identified barriers involve structural (35%) and motivational (33%) obstacles. Procedural (17%) and cultural (16%) obstacles were less likely to be explicitly mentioned. In reality, however, all groups of obstacles are interrelated (e.g. procedural obstacles may cause or contribute to the creation of structural barriers, and vice versa). Hence, a sensible approach to address any of these obstacles will require a complex intervention strategy, especially if one takes into consideration the different levels of influence that it would involve (strategic, tactical and operational) (ECB-InGenious 2013).

Project Impact on Schools

Evaluation data collected from teachers and students before their involvement in project activities confirmed the existence of serious ‘gaps’ in school-industry partnership and demonstrated how the absence of such collaboration negatively affects STEM education and students’ career aspirations.

More than half of teachers (60%) were of the opinion that their students were unable to connect school lessons in STEM subjects with their everyday lives, while the number of teachers who thought their students had a good understanding of a variety of STEM-related careers was even smaller (35%). Moreover, four out of ten students said that they were not learning about STEM jobs in school, and nearly just as much (34%) did not see any practical use for the knowledge they gain in science lessons. At the same time, students were well aware that STEM industries are very important in the society (84%) and that their achievements in STEM subjects are important for their personal future (78%).

Not surprisingly, teachers felt that their current ability to use contextual examples and career information was limited and that they needed more support in doing this. Fifty-one percent of them thought it was ‘hard to provide real-life illustrations and present-day industry examples in their lessons’. This conclusion is consistent with teachers’ responses to another statement in the baseline survey ‘I often use resources from modern industries in my teaching’: only 15% of participants stated their strong agreement with this proposition. Interviews with teachers also showed that, with a few exceptions, schools’ engagement with industries before the project was patchy and irregular. Hence, teachers were very keen to gain access to industry educational resources to help improve students’ interest and knowledge of STEM subjects by illustrating real-life examples and ‘cutting edge’ industry applications of STEM knowledge. Yet, they were less certain of other areas for collaboration, e.g. learning about STEM careers (Fig. 7), or forms and activities this relationship should involve. At the onset of the project, some teachers questioned motives of industry partners’ involvement in education and had reservations about letting them in schools.

Teachers needed additional support and more opportunities to learn about project industry partners, to understand the ‘inner workings’ of the world of business and learn about the fundamentals of school-industry collaboration. They also wanted

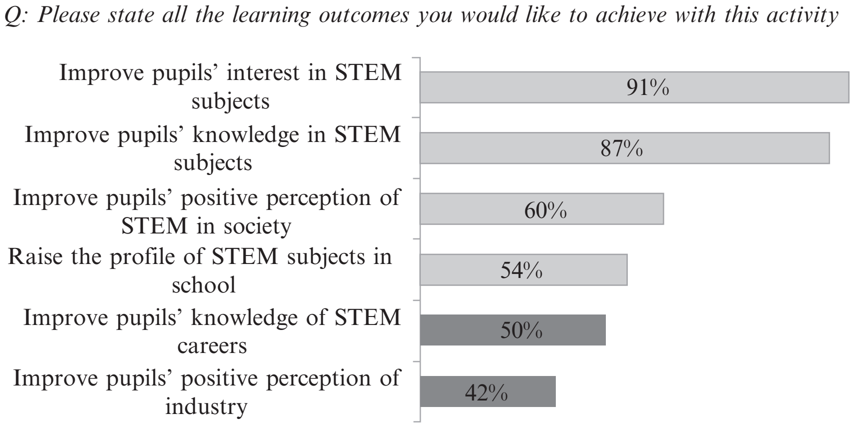

Fig. 7 Teachers' expectation of learning outcomes for students from implementing project activities ($N = 1280$)

more networking opportunities to learn from industry experts and other teacher participants and share 'best practice' in STEM enrichment activities.

> …The chance to talk with the facilitators face by face and fix all queries – personal contact is really important. Swapping experience with some of the participants, getting inspiration... (Teacher from Czech Republic, project year 1).

Using teacher and student data collected during the 3 years of the project, we were able to assess its longer-term impact on the quality of STEM teaching and learning in schools as well as on student perceptions of STEM subjects and careers. In year one, just over half (54%) of the teachers reported that there had been a high to medium increase in their use of industrial materials in their lessons. By year three, this was reported by 87% of participating teachers. Initially many teachers opted for simpler, less demanding activities, which were relatively easy to implement and which could be carried as 'stand-alone' interventions. They were equally very likely to follow a prescribed 'script' and refrained from modifying or changing the recommended activity.

However, the longer teachers remained in the project, the more confident and competent users of industry resources they became: they were implementing more activities and they were doing it in a more creative and complex way. In the first year of joining the project, teachers on average implemented fewer activities ($n = 2.3$) than in their consecutive years, this raising to 3.4 in the final year. By the end of the project, more than three quarters (77%) of teachers reported using inGenious activities in combination with other school-industry activities (both project-based and outside the project). Hence, teachers reported noticeable improvement in their ability to deliver STEM career learning activities (Fig. 8).

Moreover, the longer schools stayed in the project, the more they became engaged with different types of school-industry collaborative activities. Table 3 compares engagement in these activities as reported by both new and more experienced

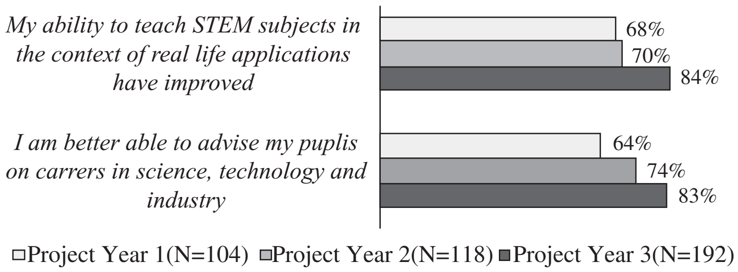

Fig. 8 Teachers' ability to provide enriched curriculum learning of STEM subjects as reported in different years of the project. The percentage of teachers agreeing/strongly agreeing with statements (Likert's four-point scale), $N = 375$

Table 3 Comparative effects of different length of project participation on school-industry collaboration

School-industry collaboration activities reported by schools with different years of project participation	Number of years spent in the project		
	New participants (*n* = 76)	1 year (*n* = 33)	2 years (*n* = 72)
Hands-on activity with industry representative	37%	56%	65%
Running/supporting/engaging in STEM club	41%	53%	65%
Hands-on activity with teacher using industry resources	52%	89%	89%
Running competition in STEM subjects	55%	81%	85%
Resources from industry used in normal classroom activity	61%	92%	82%
Professional development of teaching staff	65%	81%	83%
Visiting speaker from industry	72%	81%	87%
Visit to industry/resource centre	85%	92%	92%

participants at the start of the final year of the project. The difference between newcomers and schools that were in the project from the start is between 20 and 30 percentage points on most of the activities, especially with regard to actual involvement of industry representatives in school.

This was as much about developing a culture of learning over time as it was using particular activities and being familiar with their outputs. This appears to be what for many teachers was a pivotal point:

> I have thoroughly enjoyed being involved with inGenious over the last 3 years. It has transformed my teaching and shown me the importance of collaborations both with industry and with international colleagues. (Teacher from UK, project year 3)

When teachers reflected on how the project was affecting their students, they reported a gradual but constant improvement in student learning of STEM subjects. More importantly, this was matched by a noticeable increase in their awareness and interest in STEM careers, with the highest impact being achieving by the project final year (Figs. 9 and 10).

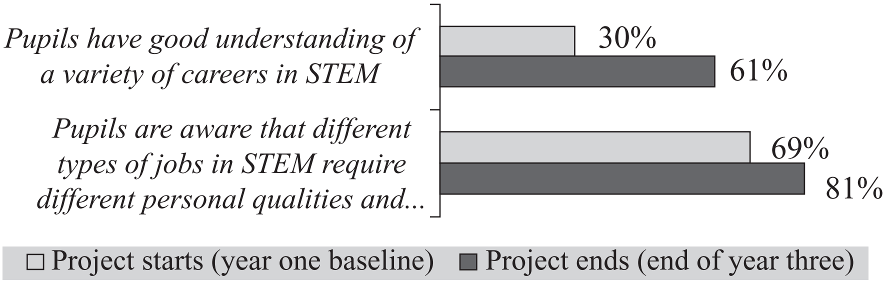

Fig. 9 Students' awareness of STEM careers reported by teachers before and after the project. The percentage of teachers agreeing/strongly agreeing with each statement (Likert's four-point scale), *N* = 375

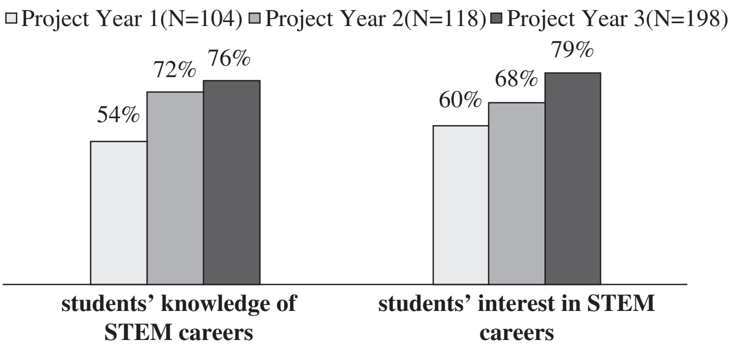

Fig. 10 Percentage of teachers in each project year who reported high and medium impact on student career perceptions (impact was measured on a four-point scale)

In the first project year, slightly more than a half of teachers defined the impact on student career learning and aspirations as high or medium, but by the end of its third year, this number was more than three quarters. A Finnish primary teacher, who participated in all 3 years of the project, described the final impact as follows:

> Thanks to this project, I think that I opened a little door to the corporate world and it aided their (i.e. students') interest in profession in general and in relation to their future.

This perception is confirmed by students' data, which showed a statistically significant positive change in young peoples' inclinations towards STEM-related careers (Fig. 11), both for primary and secondary school students.

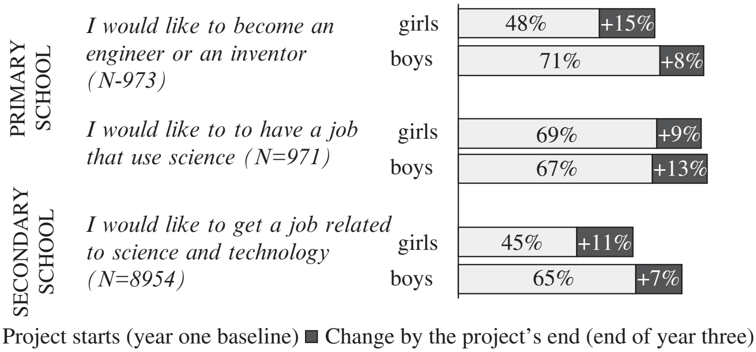

Fig. 11 Improvements in students' STEM career aspirations. The percentage of students who agreed or strongly agreed with each statement (Likert's four-point scale)

Conclusions

Considering the complexity and multidimensionality of factors that influence STEM career choices, our research has demonstrated that school-industry partnerships can provide for this complexity and have a positive role to play. However, our study has confirmed that some gaps and barriers present strong challenges to the establishment, effective implementation and sustainability of such kinds of partnership. Our analysis of a sample of European school-industry initiatives has demonstrated that present-day partnership arrangements can be of diverse nature and have considerable differences in terms of their aims, target audiences, duration, type of activities and the level of interaction between students and STEM professionals. Importantly, they also differ in their capacity to address different groups of factors known to impact young people's interest and career aspirations in STEM-related subjects (i.e. factor groups A, B, C, D).

At the same time, we have identified the prevalence of certain biases in the industry offer of educational enrichment activities, which could have a negative effect on school-industry collaborative work and create additional gaps in the provision of STEM enrichment activities. For example, industry initiatives tend to focus on secondary students at the expense of primary school groups and often overlook the need for rigorous evaluation of outcomes and impacts. Moreover, we also evidenced the existence of cultural barriers, which separate the world of education and industry and create misconceptions and suspicions about the motivation, needs and requirements of potential partners in school-industry collaborations. This has been shown as an additional negative factor that impairs collaboration and reinforces the existing gaps.

We have also shown that for a partnership to be effective, it has to be sustainable and has a long-term commitment from both sides. But such partnerships are not easy to develop and require additional structural and organisational support and guidance on how to make collaborative work experiences as worthwhile as they should (CBI 2012). In this sense, ECB-inGenious has become a successful European platform bringing schools and industry stakeholders together and creating opportunities for networking, professional learning, understanding of each other's needs, sharing of good practice and facilitation of school-industry collaboration. The project provided a stable sustainable platform for an ongoing dialogue between schools with industry experts and educational specialists, which helped to overcome many structural, procedural and cultural constraints identified in the needs analysis.

A very important enabler of this success was extensive professional development and support offered to teachers within the project. Teachers have noticeably improved their use of industry enrichment activities and STEM learning resources. However, this was a gradual process. The longer teachers stayed in the project, the more confident they became in addressing students' STEM career aspirations. This allowed them to be more creative and experimental in the classroom, engaging students in elaborate activities and achieving higher impact on student career aspirations. The evidence gathered in the project showed that it produced wider benefits, positively impacting schools' ability to maintain their current industry partnerships and develop new collaborations and links to the world of STEM industries.

Finally, we see the need for further research to identify other actions and policies that can tackle structural, motivational, procedural and cultural barriers, helping teachers effectively integrate industry support in STEM education and enabling schools to open up to real-life challenges (EC 2015b).

Acknowledgements ECB has been funded with support from the European Commission under Seventh Framework Programme, Grant agreement no: 266622. This publication reflects the views only of the authors. The Commission cannot be held responsible for any use which may be made of the information contained therein.

References

Andrée, M., & Hansson, L. (2015). Recruiting the next generation scientists and industrial engineers: How industrial actors engage in and motivate engagement in STEM initiatives. *Procedia - Social and Behavioral Sciences, 167*, 75–78.

Archer. (2013). Young people's science and career aspirations, age 10–14. ASPIRES final report. Retrieved from https://www.kcl.ac.uk/sspp/departments/education/research/aspires/ASPIRES-final-report-December-2013.pdf

Burge, B., Wilson, R., & Smith-Crallan, K. (2012). *Employer involvement in schools: A rapid review of UK and international evidence*. (NFER Research programme: From education to employment). Slough: NFER.

Business-School Connections Roundtable. (BSCR). (2011). *Realising potential: Business helping schools to develop Australia's future*. https://docs.education.gov.au/system/files/doc/other/australian_government_response_realising_potential.pdf. Accessed 23 Dec 2016.

Confederation of British Industry (CBI). (2012). *Learning to grow: What employers need from education and skills. Education and skills survey 2012*. http://www.ucml.ac.uk/sites/default/files/shapingthefuture/101/cbi_education_and_skills_survey_2012.pdf. Accessed 23 Dec 2016.

DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related aspirations across the primary–secondary divide: Evidence from two surveys in England. *International Journal of Science Education, 36*(10), 1609–1629.

ECB-InGenious. (2011a). *InGenious project. Observatory Methodology. Report to the European Commission.*

ECB-InGenious. (2011b). *InGenious project. Protocol of experimentation for the leading pilot schools. Report to the European Commission.*

ECB-InGenious. (2013). *InGenious project. Needs analysis for school-industry partnerships. Report to the European Commission.*

ECB-InGenious. (2014a). *InGenious project. European Synthesis Report. Report to the European Commission.*

ECB-InGenious. (2014b). *InGenious project. Final evaluation report. Report to the European Commission.*

European Commission. (EC). (2013). *PISA 2012: EU performance and first inferences regarding education and training policies in Europe*. http://ec.europa.eu/dgs/education_culture/repository/education/policy/strategic-framework/doc/pisa2012_en.pdf. Accessed 23 Dec 2016.

European Commission. (EC). (2015a). *EU skills Panorama 2014. Analytical highlight. Focus on STEM skills.*

European Commission. (EC). (2015b). *Science education for responsible citizenship*.

European Round Table. (ERT). (2009). *Mathematics, science & technology education report. The case for a European coordinating body*. http://www.ert.eu/sites/ert/files/generated/files/document/mst_report_final.pdf. Accessed 23 Dec 2016.

Fouad, N. (2007). Work and vocational psychology: Theory, research, and applications. *Annual Review of Psychology, 58*, 543–564.

Mann, A. (2012). *It's who you meet: Why employer contacts at school make a difference to the employment*. http://www.educationandemployers.org/wp-content/uploads/2014/06/its_who_you_meet_final_26_06_12.pdf. Accessed 23 Dec 2016.

Marriott, N., & Goyder, H. (2009). Manual for monitoring and evaluating education partnerships. http://unesdoc.unesco.org/images/0018/001851/185117e.pdf. Accessed 23 Dec 2016.

Namey, E., Guest, G., Thairu, L., & Johnson, L. (2008). Data reduction techniques for large qualitative data sets. In *Handbook for team-based qualitative research* (pp. 137–163). Plymouth: Altamira Press.

National Centre for Social Research. (NCSR). (2008). The involvement of business in education: A rapid evidence assessment of the measurable impacts. http://www.educationandemployers.org/wp-content/uploads/2014/06/involvement-of-business-in-education-dcsf1.pdf. Accessed 23 Dec 2016.

Neuman, W. L. (1997). *Social research methods: Qualitative and quantitative approaches* (3rd ed.). Boston: Allyn and Bacon.

Osgood, C. E. (1964). Semantic differential technique in the comparative study of cultures. *American Anthropologist, 66*(3), 171–200.

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research, 34*(5), 1189–1208.

Ross, K. N. (1992). Sample Design for International Studies of educational achievement. *Prospects, 22*(3), 305–316.

Savickas, M. L., Nota, L., Rossier, J., Dauwalder, J.-P., Duarte, M. E., Guichard, J., et al. (2009). Life designing: A paradigm for career construction in the 21st century. *Journal of Vocational Behavior, 75*(3), 239–250.

Sjøberg, S., & Schreiner, C. (2010). The ROSE project. An overview and key findings. Oslo.http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf. Accessed 23 Dec 2016.

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Los Angeles: Sage.

The Royal Society. (2004). *Taking a leading role*. https://royalsociety.org/~/media/Royal_Society_Content/Education/2011-06-07-Taking_a_leading_role_guide.pdf. Accessed 23 Dec 2016.

Wright, P. W. G. (Ed.). (1990). *Industry and higher education: Collaboration to improve students learning and training. The society for research into higher education*. Bristol: Open University Press.