Science Education International
37(1)_2026,47-57
https://doi.org/10.33828/sei.v37.i1.5

ORIGINAL ARTICLE

# Interest and Competence Development in School-industry Partnership: Exploring the Stratosphere

**Anssi Salonen[1]*, Ville Tahvanainen[2], Niko Kaikkonen[3]**

[1]School of Applied Educational Science and Teacher Education, University of Eastern Finland, Joensuu, Finland, [2]Competence Development Unit, Siun Sote, Joensuu, Finland, [3]City of Joensuu, Joensuu, Finland

***Corresponding Author:** anssi.salonen@uef.fi

## ABSTRACT

This study investigated how a school-industry partnership intervention influences Finnish high school students' interest in science, technology, engineering and mathematics (STEM), and their competence development through a hands-on weather balloon project. The intervention engaged students, technology education student teachers (ST), teachers, university lecturers and industry experts in collaborative design, assembly, launch and analysis activities. Using a mixed-methods approach, quantitative data from questionnaires assessed students' interest factors, perceived relevance and self-competence, while qualitative data from open-ended responses provided insight into students' experiences. The results indicated that practical engagement in an interdisciplinary collaboration and a supportive learning environment strengthened students' agency, knowledge acquisition and further interest. However, a significant discrepancy emerged between ST' higher evaluations of students' competence development and students' more modest self-assessments, particularly in technical proficiency. This gap highlights the need for clearer communication regarding learning goals, formative assessments and reflections to help students recognize their growth. As suggested by the findings, well-structured partnerships offer authentic learning aligned with curriculum goals, promoting 21st-century skills and supporting students' STEM orientation.

**KEY WORDS:** Competences, interest, intervention, science, technology, engineering and mathematics

## INTRODUCTION

Declining interest in science, technology, engineering and mathematics (STEM), and particularly in science, has forced educational trends to increasingly seek to bridge the gap between academic learning and real-world applications, with participation emphasising authentic, practical and socially meaningful learning (OECD, 2019). One prominent response has been the school-industry (-university/community) partnerships, which open classrooms to realworld problems, artefacts and professional expertise, providing students with careerconnected experiences and mentoring (Falloon, 2013; Houseal et al., 2014). Furthermore, such collaborations can strengthen students' interest, value beliefs and aspirations in STEM while supporting teachers' professional learning and curricular innovation (Kotkas et al., 2017; Salonen et al., 2019). Yet, the partnership depends on the pedagogical design: How collaborations are translated into coherent instructional teaching-learning sequences, assessment practices and opportunities for sustained sense-making. In addition to shaping students' interest and attitudes, partnership-based STEM activities also provide structured opportunities for developing transversal skills, such as problem-solving, collaboration and critical thinking. Prior studies indicate that interest and competence development are mutually reinforcing: Engaging, authentic tasks can enhance students' situational and long-term interest while simultaneously supporting the acquisition of competences needed for STEM learning and careers (e.g. Osborne, 2014; National Research Council, 2012). Integrating these elements into the partnership design is therefore essential for realizing their full educational potential. Research demonstrates that students' interest in science is closely connected to their sense of competence and subsequent skill development. When learning environments support their autonomy, relatedness and competence, students are more likely to sustain their interest (Deci and Ryan, 2000). Through experiences and constructive feedback, students' self-efficacy strengthens, encouraging deeper participation and enabling the development of competence (Bandura, 1997). Designing partnership-based STEM activities that support these motivational processes is therefore essential for fostering interest and creating the conditions for meaningful competence development.

### School-industry Partnerships as Pedagogical Design

We define school-industry(-university/community) partnerships as structured collaborations in which partners codesign and codeliver learning activities, contribute expertise and resources, and engage with students and teachers around shared artefacts and problems (Coburn and Penuel, 2016; Pattison, 2021: Sanders, 2005). Rather than treating partnerships as oneoff enrichment or guest lectures, partnerships are most educationally effective when they are realized through project- and designbased pedagogies that emphasize extended engagement, iterative problemsolving, and public products (Salonen, 2020). These approaches can yield positive effects on motivation and achievement in STEM, particularly when students engage in extended projects supported by metacognitive scaffolding (Wang et al., 2024). Similarly, design-based approaches require careful attention to group dynamics and task structures. For example, the group size and the nature of collaborative work significantly influence creativity and learning outcomes in STEM, highlighting the need to balance practical and conceptual elements and ensure sufficient duration for meaningful engagement (Han et al., 2022).

Partnerships between schools, communities and industries have emerged as a promising strategy to enhance STEM education (Attard et al., 2021) by providing students with exposure to authentic experiences, mentorships and career pathways. These collaborations are designed to promote students' interest and engagement in STEM fields or subjects and encourage future career aspirations in these fields. A key feature of such partnerships is the facilitation of direct interactions between students or teachers and professionals working in STEM. These interactions often take the form of professionals coming to schools or students attending workplaces, offering authentic insights into scientific careers and practices (Hellgren, 2016; Falloon, 2013). Most importantly, it consists of interactive elements, making it more than merely a visit. Recent studies have also emphasized the importance of structured and long-term collaborations that extend beyond one-off visits or events. For example, Sarpong et al. (2025) argue that partnerships focused on the co-creation of knowledge can lead to more meaningful and lasting educational outcomes. Such models require flexible governance, the alignment of institutional goals and a shared commitment to educational innovation.

Research has shown that personal engagement with professionals in their authentic working environments can positively influence students' attitudes toward STEM and enhance their career awareness (Houseal et al., 2014). These experiences also help to correct common stereotypes about scientists and engineers, particularly among underrepresented groups, and can play a crucial role in shaping students' STEM identities (Farland-Smith, 2009). Moreover, such partnerships provide both students and teachers with access to the latest knowledge and practices from various scientific and technical fields, enriching the educational experience and supporting more relevant and engaging teaching approaches (Salonen et al., 2019).

Despite their potential, school-industry partnerships face challenges. Accessing suitable professionals and experts can prove difficult, particularly in rural or under-resourced areas. Teachers may lack the time or support to coordinate such collaborations, and professionals may have limited availability or experience in educational engagement. In addition, the rigid curricula and lack of supportive teaching materials can hinder the integration of industry-based content into classroom instruction (Salonen, 2020; Falloon, 2013).

## Students' Interest in STEM

As a multidimensional construct, interest is shaped by both situational and individual factors (Hidi and Renninger, 2006). Situational interest refers to the temporary engagement triggered by environmental stimuli, such as novel tasks or interactive activities, whereas individual interest reflects a more enduring predisposition toward a domain. Furthermore, Krapp's person-object theory of interest (POI) provides a foundational framework, conceptualizing interest as a relational construct between an individual and a content domain (Krapp, 2002). According to this theory, interest develops when learners perceive meaningful connections between themselves and the learning object or environment, mediated by cognitive, emotional, value and quality components.

Interest often develops when learners build on existing knowledge while acquiring new information. Moderate prior knowledge, combined with opportunities to learn more, fosters curiosity and engagement (Tobias, 1994; Schraw and Lehman, 2001). An interested learner is typically independent, alert to problems, and eager to deepen understanding (Levitt, 2001). Enjoyment and emotional engagement, positive or even negative, play a role in sustaining interest (Ainley et al., 2005; Ainley and Ainley, 2011b). However, the enjoyment does not necessarily depend on the amount of knowledge acquired (Ainley and Ainley, 2011a).

Within a POI framework, the value component highlights the connection between the goals and the intentions and underlying attitudes, expectations and values (Krapp, 2002). Students engage and pursue STEM studies if they see the value for their future career goals, whereas the relevance to everyday life appears to be less important (Palmer et al., 2017). Moreover, students' perception of relevance strongly influences their interest. Many students feel STEM studies are disconnected from everyday life and societal roles (Childs et al., 2015). Integrating the real-world contexts and sustainability issues into STEM education can bridge this gap (Cigdemoglu and Geban, 2015).

Moreover, career-related information enhances the utility value of learning. Students need clear links between STEM education and future careers (Andersen and Ward, 2014). Individual interest significantly influences career choices (Potvin et al., 2020), and even those who are disinterested in STEM recognize its societal importance. Citizen science projects can strengthen vocational and societal value through promoting learners' agency and how their contributions matter (Dickinson et al., 2012; Brossard et al., 2005).

## Competence Development and Assessment in STEM

STEM interventions create structured opportunities for students to develop cognitive, practical and socio-emotional skills through inquiry, design and collaborative problem-solving. Socio-constructivism emphasize that skills emerge when learners engage in authentic tasks with social support (Vygotsky, 1978). The experiential learning theory further explains that the iterative cycles of experience, reflection and revision support deep learning and transfer (Kolb, 1984). Within STEM contexts and school-industry partnerships, such cycles occur naturally as students design solutions, test ideas and refine their work in collaboration with peers and professionals.

STEM interventions typically include problem-solving, critical thinking, collaboration and technical proficiency. Engineering design tasks strengthen students' abilities to frame problems, generate alternatives and optimize solutions (NRC, 2012). Scientific inquiry fosters evidence-based reasoning and argumentation (Osborne, 2014). Collaborative project work supports shared decision-making and distributed expertise (Barron, 2003). Similarly, the Finnish high school curriculum stresses broad-based competences (FNBE, 2019). The curriculum highlights six comprehensive competence areas: wellbeing, interaction, multidisciplinary creativity, societal participation, ethics and environment, and global-cultural skills. These goals align closely with STEM education objectives by promoting inquiry, collaboration and reflection on real-world challenges. Embedding school-industry partnerships within this framework supports authentic learning experiences that develop students' capacities for lifelong learning and responsible future work life and decision-making.

Competence development in STEM education is not only shaped by the instructional design but also by how progress is assessed and perceived by different stakeholders. Self-assessment practices encourage students to reflect on their learning processes, identify strengths and weaknesses, and take ownership of their development. Research shows that self-assessment can foster metacognitive awareness and self-regulated learning, particularly when supported by clear criteria and formative feedback (Andrade, 2019). However, the accuracy of self-assessment varies; students often overestimate or underestimate their abilities, influenced by confidence, prior experiences and the complexity of tasks (León et al., 2023). Teachers, on the other hand, tend to rely on observable performance indicators; their judgments are shaped by pedagogical beliefs, curriculum expectations and classroom dynamics (Margot and Kettler, 2018). While teachers generally perceive competence development more conservatively than students (Nguyen et al., 2020), their commitment to novel partnerships can raise optimism (Coburn and Penuel, 2016; Pattison, 2021). Research suggests a mismatch between the student and teacher perceptions of specific competences. While both groups value problem-solving and collaboration, students often report higher confidence in socio-emotional and teamwork skills than what teachers acknowledge (Lämsä et al., 2023). Conversely, teachers may underestimate students' informal learning gains achieved through peer or professional interaction. As such, bridging these gaps requires dialogic assessment approaches, the co-construction of criteria, and iterative feedback cycles that integrate both perspectives.

### Aim of the Study and Research Questions

This study integrates multiple complementary theoretical frameworks to examine both interest and aspirations, and competence-related outcomes of a school-industry partnership STEM intervention. Interest development theories, particularly POI theory, provide the basis for analyzing how authentic, real-world activities stimulate situational and emerging individual interest in STEM, addressing RQ1. Competence development frameworks inform the assessment of transversal, cognitive and technical skills fostered through the intervention, forming the foundation for RQ2. Socio-constructivist perspectives connect these dimensions by framing learning as a socially mediated process occurring through collaboration with peers, teachers and industry experts. Together, these frameworks allow for a holistic examination of how interest and competence co-develop within authentic STEM partnership contexts.

RQ1: How school-industry partnership intervention can affect students' interest in STEM?

RQ2: How do student teachers (ST)' and students' perceptions of competence development differ in STEM intervention?

## METHODS

The context of this case study is the collaboration between the local high school, industry and technology education teacher education. The partnership started when a high school science teacher wanted to harness alumni enterprises to good use in learning. After one successful intervention, teacher education lecturers and their students joined the partnership to promote the pedagogy of technology education and STEM. Two weather balloons were sent, one with industrial instruments and the other with student-made instruments. This study, with both quantitative and qualitative approaches, provides a deeper understanding of how such school–industry partnerships work, what the implications are for students' interest factors toward STEM, and how ST and students perceive skill development in the intervention's context. With this case study approach, we are not seeking generalised results but to explore insights about novel approaches in partnerships (Cohen et al., 2011).

### Participants and the Intervention

The participants in this study comprised 16 high school students (16–18 years of age) from an elective course called "Sky and Space," 15 technology education ST and their respective teachers and lecturers from the course called "Multidisciplinary technology education." In their course objectives, both courses emphasize multidisciplinary and creativity within the design and engineering processes, and collaborative partnerships with different stakeholders. In this school-industry partnership, two main industry partners were involved in the designing and implementation of the intervention: A world-leading meteorological and hydrological measurement instrument provider, and a biodiversity and geoinformation mapping company. Other minor partners were local and national air traffic and media organizations, whose roles were more supportive or providing suitable conditions for the intervention implementation.

Before the implementation, two preparatory planning meetings were held, involving representatives from the school, university and industry partners. These meetings focused on clarifying the roles and expectations of each stakeholder, ensuring a shared understanding of the intervention. Practical arrangements, such as scheduling visits and aligning calendars, were also discussed. The learning objectives were co-designed, reflecting the curriculum with both high school and teacher education. This joint planning laid the foundation for a coherent intervention. The high school teacher and university lecturers were responsible for carrying out the intervention. ST were briefed of the intervention, and given the role to provide short teaching sessions on various steps of the process: Arduino coding, electronics, using hand and machine tools, creating parachutes, and so forth. All participants were assigned to small groups in which the ST were responsible for guiding them through the designing and engineering process. Consequently, they were also asked to list objectives and outcomes for the intervention, which were further used as part of the data collection questionnaire.

The intervention (Table 1) consisted of eight phases. The sessions were organized in a fully prepared technology and engineering workshop with various tools and possibilities to design, tinker and make prototypes of electronics, metal, wood, plastics, and fabrics. In fact, no student ideas or tests were restricted by the available tools and materials.

The overall aim of the intervention was to design and engineer a weather balloon (Figure 1) that would provide information from the stratosphere (Figure 2) for the groups to analyze and learn through inquiries about science and scientific concepts, as well as the product design, industry, engineering and reporting the results.

## Data Collection

After the intervention, the students answered a questionnaire including an intervention evaluation research instrument, with 23 Likert items on a 4-point scale concerning interest, relevance (individual, societal and vocational) and learning attribute variables (Kotkas et al., 2017). In addition, the questionnaire included selected 30 competences from 21st century skills,

**Table 1: Intervention description**

| Phase of the intervention | Activities | School-industry links |
|---|---|---|
| Introduction | Teachers and lecturers introduced the project. Groups were formed, and student teachers led an initial short session to get to know each other. | Industry partners introduced themselves and their focus of work, some face-to-face and some online. |
| Learning about technologies | Student teachers held two short sessions for their own groups. One about the basics of Arduino and electronics, and the second about how to use the tools and machines in the workshop. | Industry links were made with connecting how these knowledge and skills are useful in different careers. |
| Designing | Designing the satellite box, instruments and parachutes. Calculating payload and parachute size. | Industry partners provided authentic instruments to inspire the students' work. Information and shared tips on how to design the weather balloon. |
| Building | Building the satellite box. Assembling and coding the Arduino instruments. | During the work, students had the opportunity to tinker and learn more about the authentic measuring instruments and the companies behind them. Connections between their prototype and industry-made instruments. |
| Testing the prototypes | Testing parachutes, by throwing them down from the roof and calculating descent rates with the correct payload. Testing GPS-accuracy and reliability.<br>Stress-testing the satellite box. | |
| Launch preparations | Finishing the satellite and instruments. Ensuring everything is attached and secured. Forecasting the launch day route with simulation.<br>Aviation legislation and making NOTAM. Media coverage. Message inside the balloon for third-party finders. | Local and national Air traffic authorities were involved. Their instructions and knowledge were used to provide students with knowledge about aviation legislation and what professionals work in that field. |
| Launch and retrieving the satellite | Launching the weather balloon and following the path. As the weather conditions were difficult, the flight continued late in the evening, and the landing site was 70 km away from the school, the decision was made that students would not participate in retrieving the balloon. Finally, two teachers retrieved the weather balloon from the forest, very close to a big lake. | Industry partner discussed their company and his work as a Product Line Manager with the students. He further presented how their state-of-art equipment work with meteorology data. Both the industry-made satellite and one of the student satellites were launched. Media was present, and they published a news article of it on the university webpage. |
| Reporting | Data collection and analysis<br>Reporting the data and analysis<br>Presenting the results and project. | Reports with the results were shared with the industry, and they sent their gratitude for the data and encouraged students to work in the field. |

**Figure 1:** The weather balloon satellite with the orange-transparent parachute attached to it. Green power bank powered 360-camera and Arduino Uno with GPS-module, BME280 and BS18B20 sensors

**Figure 2:** The last 360 picture from 18 km above sea level before the power bank shut down due to the extreme cold (−60°C)

STEM competence and working life skills frameworks (Binkley et al., 2012; Hu and Guo, 2021). Students were asked, using Likert items on a 4-point scale of their perceptions how these competences developed during the intervention. ST had a similar questionnaire, although the questions were asked in the form of assessing the intervention's instructional design and how they perceived student competence development. Students were also asked with two open-ended questions about what increased or declined their interest during the intervention. Both questionnaires were in electronic form, and participation was voluntary. In the questionnaire, permission to use their answers for research was first requested. For students of minor age, a guardian's consent was obtained for them to participate. Ultimately, each participant decided their participation by themselves. The school's consent was secured from the head principal, and the university's consent from the head of department.

### Data Analysis

The calculation of descriptive statistics, including the means and standard deviations (SDs), of the intervention evaluation research instrument variables (interest, relevance and learning attributes) was followed by the content analysis of the related open-ended questions.

The Cronbach's alphas were calculated for the competence category variables (Table 2), after which the descriptive statistics were calculated separately for ST's and students' (S) ratings across competence categories. Systematic differences in the means across all categories suggested further analysis between the groups. Therefore, independent samples t-tests were conducted to examine the differences between ST's assessments and students' self-perceptions regarding the development of skills during the intervention. ST evaluated how the intervention supported students' skill development, whereas students assessed their own progress. Due to the small sample size, we seek for exploratory and preliminary findings, supported with qualitative excerpts.

## RESULTS

### RQ1: Student Interest in STEM through Weather Balloon Intervention

To address RQ1, which examines how the school-industry partnership intervention affected students' interest in STEM, both quantitative and qualitative data were analyzed focusing on perceived cognitive, relevance, value, agency and learning aspects. Overall, students reported high levels of several key interest variables regarding the weather balloon intervention. The quantitative data in Figure 3 reveal that students felt particularly motivated by the opportunity to gain new, useful knowledge.

However, the transition of this knowledge and learned competences in future endeavors, including personal, social and vocational aspects, is lower. Moreover, there are several elements, such as their interest and curiosity sparked by the topic, their sense of agency and ability to express and utilize skills, and the enjoyable and relaxed atmosphere of the learning environment, all of which contributed to their overall engagement, motivation and positive learning experience.

When looking into their qualitative answers, students emphasized the value of hands-on technical engagement for knowledge, particularly programming and assembling components. These activities were described as rewarding opportunities to develop new skills and apply problem-solving strategies, as one student noted.

> *"Building the Arduino and solving problems in programming. I was able to develop skills in a topic I had no prior knowledge of, and finding and solving problems during the task made me have a rewarding feeling."*

Regarding personal and social values, students appreciated the collaborative nature of the project and the interdisciplinary approach. This integration was perceived as novel and meaningful, particularly with bringing practical technology and engineering to the high school context.

> *"A completely new topic for me [...] The encounter between natural sciences and technology and engineering was new and interesting. Weather and related phenomena affect everyone, and it was fascinating to see and learn how devices can collect data."*

**Table 2: Competence instrument with Cronbach's alphas and exemplary items**

| Competence category | Number of items | α | Sample items |
|---|---|---|---|
| Social skills | 9 | 0.9 | |
| Collaboration | 3 | 0.76 | Interpreting others' information; Collaboration with others |
| Communication | 3 | 0.82 | Listening to others; Speaking to others in a group |
| Responsibility and safety | 3 | 0.71 | Taking responsibility for one's actions; Proposing responsible actions |
| Cognitive and metacognitive skills | 14 | 0.87 | |
| Creativity | 3 | 0.8 | Asking creative questions;<br>Generating new solutions |
| Critical thinking and reasoning | 6 | 0.84 | Scientific reasoning; Making justified decisions |
| Problem-solving process | 5 | 0.82 | Applying knowledge in new situations; Debugging and troubleshooting |
| Technical proficiency | 4 | 0.62 | Programming electronic devices; Operating machinery and tools |

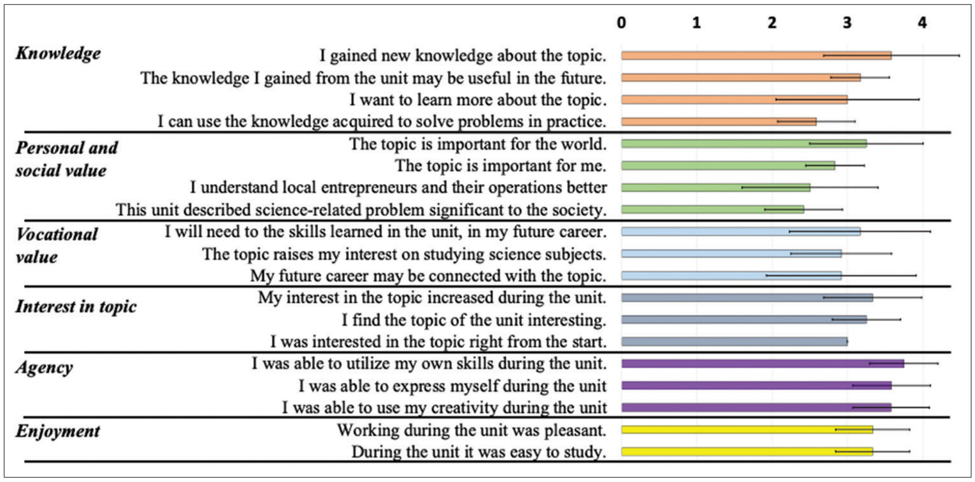

**Figure 3:** Student interest factors and their mean ratings after the intervention

Although there were no explicit mentions related to vocational value in the open-ended answers, plenty of students mentioned several competences they needed to use while working with the weather balloon. They simply did not see the connection between these competences and working life or their future careers.

In terms of general interest in the topic, novelty and curiosity emerged as strong motivators. Students expressed excitement about encountering an unexpected topic and working on something that felt unique compared to traditional coursework.

> *"An interesting topic that I did not expect to come across."*
> *"The project was extremely interesting! I knew almost nothing about the topic, and it felt crazy to do something like this."*

Students valued the freedom and enjoyment embedded in the learning environment. A relaxed and inspiring atmosphere, combined with collaborative activities, contributed to agency, motivation and engagement:

> *"A free and inspiring atmosphere made working motivating."*
> *"Definitely a pleasant atmosphere, because it made the work enjoyable."*
> *"Doing things together and the excitement of launching the balloon."*

## RQ2: Differences in Perceptions of Competence Development

RQ2 explores differences between ST's and students' perceptions of competence development during the intervention. Comparative analyses of questionnaire data were conducted both to recognize students' competence self-assessment and to identify systematic differences across competence domains between students and teachers. Overall, the students acknowledged development across domains but perceived technical skills as the most challenging area. The students reported modest improvements across the competences (Table 3).

As shown in the table, social and responsibility averaged 2.26 (SD = 0.59), and cognitive and metacognitive Skills, 2.30 (SD = 0.49). However, technical proficiency received the lowest mean of 1.89 (SD = 0.35), despite being a central focus of the intervention. This suggests that the students felt less confident about their progress in hands-on tasks, such as building and programming electronic devices. ST showed similar tendencies, albeit with much higher expected competence developments when they assessed the students' competence development in the intervention.

Significant differences emerged across all three main categories. For social and responsibility skills, ST reported

**Table 3: Student teachers' and students' perceptions of competence development and the statistical difference between them**

| Competences | Student teachers[a] | | Students[b] | | *t* (29) | p-value | Cohen's *d* |
|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | | | |
| Social and responsibility | 2.84 | 0.63 | 2.26 | 0.59 | 2.87 | 0.007 | 0.95 |
| Collaboration | 2.73 | 0.75 | 2.38 | 0.89 | 1.3 | 0.205 | 0.5 |
| Communication | 3.02 | 0.67 | 2.27 | 0.71 | 3.02 | 0.005 | 0.8 |
| Responsibility and safety | 2.78 | 0.66 | 2.10 | 0.48 | 3.25 | 0.003 | 0.85 |
| Cognitive and metacognitive | 2.85 | 0.60 | 2.30 | 0.49 | 3.04 | 0.005 | 1.01 |
| Creativity | 2.80 | 0.70 | 2.46 | 0.64 | 1.42 | 0.167 | 0.45 |
| Critical thinking and reasoning | 2.82 | 0.62 | 2.26 | 0.52 | 2.75 | 0.010 | 0.9 |
| Problem-solving process | 2.93 | 0.63 | 2.19 | 0.49 | 3.7 | <0.001 | 1.1 |
| Technical proficiency | 2.80 | 0.45 | 1.89 | 0.35 | 6.64 | <0.001 | 2.27 |

N=30, [a]n=15, [b]n=16. M: Mean, SD: Standard deviation

higher levels of skill development (M = 2.84, SD = 0.63) compared to students (M = 2.26, SD = 0.59), t(29) = 2.87, p = 0.007, Cohen's d = 0.95. This indicates that ST perceived the intervention as more effective in fostering social competences than students did themselves.

Similarly, for cognitive and metacognitive skills, ST's ratings (M = 2.85, SD = 0.60) were significantly higher than students' ratings (M = 2.30, SD = 0.49), *t*(29) = 3.04, p = 0.005, Cohen's *d* = 1.01. This suggests that ST observed greater improvements in students' thinking and reasoning processes than students acknowledged.

The largest difference was found in technical proficiency, where ST scored students markedly higher (M = 2.80, SD = 0.45) than students scored themselves (M = 1.89, SD = 0.35), t(29) = 6.64, p < 0.001, Cohen's d = 2.27. This substantial effect size highlights a pronounced discrepancy in the perceptions of technical skill development, with ST viewing the intervention as highly impactful in this domain.

While significant differences were already found on the main competence category level, we conducted similar tests for subcategories and found that the difference was not significant in all of them. Further, individual competences are reported on exploratory and exemplary levels with means and SDs.

Social and responsibility included three subcategories: collaboration, communication, and responsibility and safety. Differences were not uniform across these dimensions.

For collaboration, no significant difference was observed between ST and students, p = 0.205. Both groups reported similar levels of collaborative abilities. For instance, the skill "Collaboration with others" was rated M = 3.27 (SD = 0.70) by ST, and M = 2.63 (SD = 0.96) by students. Although ST's ratings ranked slightly higher, the difference was not statistically significant, suggesting that the perceptions of teamwork were relatively aligned.

In contrast, communication revealed a significant difference, p = 0.005, with ST rating communication skills higher than students. A meaningful example is "Listening to others," scored at M = 3.27 (SD = 0.70) by ST and M = 2.25 (SD = 0.86) by students. Similarly, "Speaking to others or a group" was rated M = 3.13 (SD = 0.74) by ST and M = 2.44 (SD = 0.89) by students. These findings indicate that ST perceived stronger gains in interpersonal communication, particularly in listening and oral expression.

The subcategory responsibility and safety also showed a significant difference. ST rated "Safety awareness" at M = 2.40 (SD = 0.83), whereas students rated it at M = 1.75 (SD = 0.58). Another illustrative skill, "Taking responsibility for one's actions," was scored M = 3.13 (SD = 0.64) by ST and M = 2.50 (SD = 0.89) by students. These results suggest that ST observed a greater improvement in students' sense of responsibility and adherence to safety protocols than students reported.

Cognitive and metacognitive included creativity, critical thinking, reasoning, and problem-solving. Differences were significant for critical thinking and problem-solving but not for creativity.

For creativity, no significant difference was found. For example, "Acting creatively" was rated similarly by ST (M = 2.53, SD = 0.83) and students (M = 2.69, SD = 0.87). Likewise, "Asking creative questions" received ratings of M = 2.53 (SD = 0.92) from ST and M = 2.06 (SD = 0.77) from students, indicating some variation but not enough to reach statistical significance. These findings suggest that both groups considered the creative engagement moderately developed.

Conversely, critical thinking and reasoning exhibited a significant difference. A striking example is "Critical thinking," rated at M = 3.27 (SD = 0.70) by ST and M = 1.94 (SD = 0.93) by students. Similarly, "Making justified decisions" was scored M = 2.93 (SD = 0.80) by ST and M = 2.13 (SD = 0.62) by students. These results indicate that ST perceived substantial gains in analytical reasoning and decision-making, whereas students were more conservative in their self-assessments.

The problem-solving process showed the most pronounced difference within this category. For instance, "Problem-solving" was rated M = 3.13 (SD = 0.83) by ST and M =

2.31 (SD = 0.79) by students. Similarly, "Debugging and troubleshooting" received ratings of M = 2.87 (SD = 0.83) from ST and M = 2.00 (SD = 0.63) from students. These findings suggest that ST observed significant improvement in students' ability to approach and resolve complex problems, while students reported more modest progress.

Technical proficiency demonstrated the strongest and most consistent differences between groups. ST rated skills, such as "Building electronic devices," at M = 3.40 (SD = 0.63), whereas students rated the same skill at M = 2.00 (SD = 0.82). Similarly, "Programming electronic devices" was scored M = 3.07 (SD = 0.80) by ST and M = 2.00 (SD = 0.82) by students. Even basic tasks, such as "Using hand tools," showed a gap, with ST rating it at M = 2.40 (SD = 0.83) and students, M = 1.88 (SD = 0.72). These results underscore a substantial discrepancy in the perceptions of technical skill acquisition, with ST viewing the intervention highly effective on providing technical proficiency.

## DISCUSSION

The results indicate that students' interest was primarily triggered by situational factors, such as novelty, hands-on activities, and collaborative experiences, aligning with Hidi and Renninger's findings (2006) for the situational interest emerging from engaging tasks and environments. Moreover, students' enthusiasm for programming and technical assembly reflects Krapp's (2002) POI, as these activities fostered meaningful connections between learners and the content.

The strong emphasis on collaboration and positive atmosphere resonates with Ainley and Ainley's (2011b) findings that enjoyment and emotional engagement sustain interest, even when knowledge acquisition is secondary. Similarly, the appeal of novelty and project uniqueness supports earlier research, suggesting that unfamiliar, authentic tasks enhance situational interest (Borrows, 2004). However, the absence of vocational value in students' responses contrasts with studies emphasising the importance of perceived relevance and career connections for long-term interest development (Palmer et al., 2017; Salonen, 2020). This suggests that while the intervention successfully stimulated situational interest, it may not have strengthened individual interest or utility value.

While the results indicate that the intervention fostered high situational interest (Figure 3) through novelty, enjoyment, agency and authentic engagement, the students simultaneously reported modest development of competences (Table 3), particularly technical proficiency. This pattern is theoretically consistent with interest development and person–object interest theories, which suggest that enjoyment and engagement can emerge even when learners perceive their knowledge and skills as incomplete (Hidi and Renninger, 2006; Ainley and Ainley, 2011a). From the perspective of self-efficacy theory, students' lower competence ratings likely reflect increased awareness of task complexity rather than limited learning (Bandura, 1997). Authentic engineering activities such as programming, electronics and iterative prototyping often involve uncertainty and failure, which can temporarily undermine learners' confidence despite ongoing competence development. Research on self-assessment further suggests that students tend to underestimate their progress in complex, non-traditional learning environments where success criteria are implicit and learning outcomes are process-oriented rather than standardised (Andrade, 2019; León et al., 2023). Thus, the combination of high interest and modest self-assessed competence highlights a characteristic tension of authentic STEM learning contexts, underscoring the importance of formative feedback and reflection to support the co-development of interest and self-efficacy.

Furthermore, the study reveals a consistent and substantial discrepancy between teachers' and students' perceptions of skill development during a transdisciplinary STEM weather-balloon intervention. Across all competence areas – technical proficiency, problem-solving, and transversal skills – teachers rated student progress significantly higher than students did. The weak, non-significant correlation between the two groups' profiles indicated not only a difference in the magnitude of perceived gains but also a divergence in which skills each group believed improved the most. This dual gap underscores the need to examine how learning goals are communicated, how learning is assessed, and how the roles of teachers and students within partnership-based STEM environments shape perception.

Teachers' optimism regarding the intervention can be partly explained by their professional orientation toward pedagogical innovation. STE(A)M education is widely regarded by educators as a transformative approach that fosters creativity, collaboration, and critical thinking (Perignat and Katz-Buonincontro, 2019; Dare et al., 2021). In addition, ST's active participation in instruction and partnership can amplify optimism by promoting commitment to the project and tendency to interpret outcomes in a more favorable light (Coburn and Penuel, 2016; Pattison, 2021). This aligns with research on the instructional design, which suggests that educators' beliefs about the efficacy of active learning strategies strongly shape their evaluations of student progress (Guzey et al., 2017). In addition, since the STs are from technology education, they may expect the interventions to promote safety awareness and technical skills. Conversely, for students, the lower self-ratings are consistent with the self-efficacy theory, suggesting that learners under-estimate their competence when tasks are novel, complex or interdisciplinary (Bandura, 1997; Syed et al., 2019). The intervention required programming, building electronic devices, and engineering physical prototypes, skills that typically require sustained practice to feel familiar. Students' low ratings in technical proficiency likely reflect encounters with authentic engineering uncertainty rather than the absence of learning. Similarly, the literature on scaffolding highlights that students often perceive progress as limited when cognitive demands are high, and the criteria for success remain implicit (Lin and Tsai, 2020). Furthermore, students often struggle to recognize incremental progress in non-traditional learning contexts, where success is measured through creative output rather than standardised metrics (cf. León et al., 2023). Interventions with design or engineering processes may worsen it, as students face iterative prototyping, and inevitably, failures. Students might see them as indicators of poor performance rather than growth (Farland-Smith, 2009).

The gap between ST and students' perceptions also reflects broader dynamics in partnerships. STEM interventions are seen as opportunities to connect classroom learning with real-world contexts, leveraging partnerships with scientists, industry professionals and community organizations to enrich instruction to frame competence development (Falloon, 2013; Pattison, 2021; Sanders, 2005). Therefore, ST's enthusiasm for these partnerships may amplify their perception of student gains, as they associate authentic engagement with enhanced learning outcomes (Houseal et al., 2014; Coburn and Penuel, 2016). Conversely, students may experience these partnerships as distant or disconnected, particularly if roles and expectations are not clearly communicated (cf. Farland-Smith, 2009). This misalignment underscores the importance of designing interventions that make the relevance and value of external collaborations explicit to learners.

### Limitations

Teachers in this study were well informed by curricular frameworks and professional development and therefore, attuned to competences, such as critical thinking, collaboration, and creativity, all of which STEM activities are intended to cultivate. Students, however, may have prioritized tangible outcomes, such as completing a project or mastering a technical tool. The project itself and the outcomes of this intervention were challenging and sometimes out of students' competence comfort zone; therefore, students may have undervalued their progress in such domains. Another factor contributing to perception gaps may have been the lack of transversal skills visibility in different phases of the intervention. Formative assessment strategies, including self-reflection, peer feedback, and digital portfolios, could have helped bridge this gap by making learning processes more visible and meaningful throughout the project.

## CONCLUSION

School-industry partnerships offer a promising avenue for enhancing STEM education by making learning more relevant, engaging, and connected to real-world careers, consequently, increasing students' interest in STEM. These collaborations can provide authentic contexts for problem-solving, expose students to emerging technologies, and foster transversal skills such as critical thinking, creativity, and collaboration. However, the findings of this study underscore that the mere presence of partnerships and innovative instructional designs does not guarantee that students will perceive significant competence development. This means that strong engagement does not automatically translate into high self-confidence in skills, especially in complex and professionally demanding STEM tasks. From a self-efficacy perspective, students' lower competence ratings may reflect heightened awareness of task difficulty rather than limited learning. While teachers often view STEM partnerships as highly effective, students report more modest gains, particularly in technical proficiency and problem-solving. The difference between the teacher and student perceptions of skill development in STEM contexts reflects complex interactions among the instructional design, learners' self-efficacy, and partnership dynamics, suggesting that the benefits of such interventions may be more visible to educators than the learners themselves.

The further implications of our findings are twofold. First, they highlight the need for interventions that explicitly communicate learning objectives and success indicators to students. Making competence development visible through formative assessment, structured reflection, and feedback is essential for supporting students' metacognitive awareness and self-efficacy alongside interest. Second, they call for professional development that equips teachers to interpret student experiences accurately, balancing enthusiasm for innovative methods with critical appraisal of outcomes. Such efforts can help ensure that the benefits of STEM education are both realized and perceived by learners.

For practice, the findings emphasize the importance of designing STEM partnership interventions that balance authenticity with accessibility. Structured formative assessment practices and targeted support can help students make sense of their progress and build confidence in technical domains. At the same time, teacher education programs should provide preparation for interpreting student experiences critically, and to design partnership-based learning that foster both engagement and confidence. Partnerships should move beyond the symbolic engagement to provide structured, scaffolded experiences that make learning objectives explicit and attainable for students. The clear communication of the criteria for success, formative assessment practices, and opportunities for reflection can help students recognize and articulate their progress, bridging the gap between teacher expectations and student perceptions. Furthermore, interventions should be designed to balance authenticity with accessibility, ensuring that tasks are challenging yet supported by adequate resources and guidance.

Future research should explore how students' perceptions of their skill development evolve during longer or multi-phase partnership activities, and how reflection, feedback, and performance-based assessments might reduce the gap between teacher and student perspectives. Further work could also examine how partnership structures influence teacher expectations, and what forms of professional development best support the accurate and equitable assessment of learning in authentic STEM contexts. By advancing these lines of inquiry, research can contribute to partnership models that simultaneously strengthen student learning, teacher capacity, and the long-term sustainability of school-industry collaboration.

## ETHICAL APPROVAL

No further ethical approval was needed according to University's Research Ethics Committee guidelines.

## INFORMED CONSENT

Participants' informed consent was collected from all participants. All participants were over 16 and according to Finnish National Board on Research Integrity, no guardian consent was needed, but they were informed.

## STATEMENT REGARDING RESEARCH INVOLVING HUMAN PARTICIPANTS AND/OR ANIMALS

This study involved human participants and was conducted in accordance with the ethical standards of the institutional research committee and Finnish National Board on Research Integrity.

## CONSENT TO PARTICIPATE

Participants' informed consent was collected. University, school and city consent to participate on the research was secured before the research.

## CONSENT TO PUBLISH

All consents to publish are secured.

## FUNDING

This work has not received any external funding.

## AUTHORS' CONTRIBUTIONS

All authors contributed to the intervention and study conception and design. Material preparation. Data collection was done by Anssi Salonen, Ville Tahvanainen and Niko Kaikkonen. Analysis was conducted by Anssi Salonen. The first version of the manuscript was drafted by Anssi Salonen and other authors contributed on the manuscript. All authors approved the final manuscript.

## COMPETING INTERESTS

The authors declare no conflicts of interest or competing interest.

## DATA AVAILABILITY

Parts of the data can be made available on request.

## REFERENCES

Ainley, M., & Ainley, J. (2011a). A cultural perspective on the structure of student interest in science. *International Journal of Science Education,* 33(1), 51-71.

Ainley, M., & Ainley, J. (2011b). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology,* 36(1), 4-12.

Ainley, M., Corrigan, M., & Richardson, N. (2005). Students, tasks and emotions: Identifying the contribution of emotions to students' reading of popular culture and popular science texts. *Learning and Instruction,* 15(4), 433-447.

Andersen, L., & Ward, T.J. (2014). Expectancy-value models for the STEM persistence plans of ninth-grade, high-ability students: A comparison between Black, Hispanic, and White students. *Science Education,* 98(2), 216-242.

Andrade, H.L. (2019). A critical review of research on student self-assessment. *Frontiers in Education,* 4, 87.

Attard, C., Berger, N., & Mackenzie, E. (2021). The positive influence of inquiry-based learning teacher professional learning and industry partnerships on student engagement with STEM. *Frontiers in Education,* 6, 693221.

Bandura, A. (1997). *Self-Efficacy: The Exercise of Control.* United states: Freeman.

Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences,* 12(3), 307-359.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In: Griffin, P., McGaw, B., & Care, E. (Eds.), *Assessment and Teaching of 21st Century Skills* Netherlands: Springer, pp. 17-66.

Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education,* 27(9), 1099-1121.

Borrows P., (2004), Chemistry trails. In: Braund M. and Reiss M. (Eds.) *Learning science outside the classroom* London: Routledge-Falmer, pp. 151-168.

Childs, P., Hayes, S., & O'Dwyer, A. (2015). Chemistry and everyday life: Relating secondary school chemistry to the current and future lives of students. In: Eilks, I., & Hofstein, A. (Eds.), *Relevant Chemistry Education - From Theory to Practice.* United States: Sense Publishers, pp. 33-54.

Cigdemoglu, C., & Geban, O. (2015). Improving students' chemical literacy levels on thermochemical and thermodynamics concepts through a context-based approach. *Chemistry Education Research and Practice,* 16(2), 302-317.

Coburn, C.E., & Penuel, W.R. (2016). Research-practice partnerships in education: Outcomes, dynamics, and open questions. *Educational Researcher,* 45(1), 48-54.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research Methods in Education*. 7th ed. United Kingdom: Routledge.

Dare, E.A., Keratithamkul, K., Hiwatig, B.M., & Li, F. (2021). Beyond content: The role of STEM disciplines, real-world problems, 21st century skills, and STEM careers within science teachers' conceptions of integrated STEM education. *Education Sciences,* 11(11), 737.

Deci, E.L., & Ryan, R.M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry,* 11(4), 227-268.

Dickinson, J., Shirk, J., Bonter, D., Bonney, R., Crain, R., Martin, J., Phillips, T., & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment,* 10(6), 291-297.

Falloon, G. (2013). Forging school-scientist partnerships: A case of easier said than done? *Journal of Science Education and Technology,* 22(6), 858-876.

Farland-Smith, D. (2009). Exploring middle school girls' science identities: Examining attitudes and perceptions of scientists when working "side-by-side" with scientists. *School Science and Mathematics,* 109(7), 415-427.

Finnish National Board of Education. (2019). *National Core Curriculum for General Upper Secondary Schools.* Helsinki: FNBE.

Guzey, S.S., Moore, T.J., & Harwell, M. (2016). Building up STEM: An analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering*

*Education Research*, 6(1), 2.

Han, J., Park, D., Hua, M., & Childs, P. R. N. (2022). Is group work beneficial for producing creative designs in STEM design education? *International Journal of Technology and Design Education*, 32, 2801-2826

Hellgren, J.M. (2016). *Students as Scientists: A Study of Motivation in the Science Classroom* [Doctoral dissertation]. Umeå University.

Hidi, S., & Renninger, K.A. (2006). The four-phase model of interest development. *Educational Psychologist,* 41(2), 111-127.

Houseal, A.K., Abd-El-Khalick, F., & Destefano, L. (2014). Impact of a student-teacher-scientist partnership on students' and teachers' content knowledge, attitudes toward science, and pedagogical practices. *Journal of Research in Science Teaching,* 51(1), 84-115.

Hu, W., & Guo, X. (2021). Toward the development of key competencies: A conceptual framework for the STEM curriculum design and a case study. *Frontiers in Education,* 6, 684265.

Kolb, D.A. (1984). *Experiential Learning : Experience as the Source of Learning and Development.* United States: Prentice-Hall.

Kotkas, T., Holbrook, J., & Rannikmäe, M. (2017). A theory-based instrument to evaluate motivational triggers perceived by students in STEM career-related scenarios. *Journal of Baltic Science Education,* 16(6), 836-854.

Krapp, A. (2002). An educational-psychological theory of interest and its relation to self-determination theory. In: Deci, E.L., Ryan, R.M. (Eds.), *The Handbook of Self-Determination Research.* United States: University of Rochester Press, pp. 405-427.

Lämsä, J., Virtanen, A., Tynjälä, P., Maunuksela, J., & Koskinen, P. (2023). Exploring students' perceptions of self-assessment in the context of problem solving in STEM. *LUMAT: International Journal on Math, Science and Technology Education,* 11(2), 35-59.

León, S.P., Panadero, E. & García-Martínez, I. (2023) How accurate are our students? A meta-analytic systematic review on self-assessment scoring accuracy. *Educational Psychology Review*, 35, 106.

Levitt, K.E. (2001). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education,* 86(1), 1-22.

Lin, C.L., & Tsai, C.Y. (2020). The effect of a pedagogical STEAM model on students' project competence and learning motivation. *Journal of Science Education and Technology,* 30(5), 112-124.

Margot, K.C., & Kettler, T. (2018). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education,* 5(2), 2.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* United states: The National Academies Press.

Nguyen, T.T.K., Nguyen, V.B., Lin, P.L., Lin, J., & Chang, C.Y. (2020). Measuring teachers' perceptions to sustain STEM education development. *Sustainability,* 12(4), 1531.

OECD. (2019). *OECD Learning Compass 2030: A Series of Concept Notes.* OECD Publishing.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education,* 25(2), 177-196.

Palmer, T.A., Burke, P.F., & Aubusson, P. (2017). Why school students choose and reject science: A study of the factors that students consider when selecting subjects. *International Journal of Science Education,* 39(6), 645-662.

Pattison, N.P. (2021). Powerful partnership: An exploration of the benefits of school and industry partnerships for STEM education. *Teachers and Curriculum,* 21(2), 17-25.

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity,* 31, 31-43.

Potvin, P., Hasni, A., Sy, O., & Riopel, M. (2020). Two crucial years of science and technology schooling: A longitudinal study of the major influences on and interactions between self-concept, interest, and the intention to pursue S&T. *Research in Science Education*, 50(5), 1739-1761.

Salonen, A. (2020). *Career-Related Science Education: Instructional Framework Promoting Students' Scientific Career Awareness and the Attractiveness of Science Studies and Careers* [Doctoral Dissertation, University of Eastern Finland].

Salonen, A., Kärkkäinen, S., & Keinonen, T. (2019). Teachers co-designing and implementing career-related instruction. *Education Sciences,* 9(4), 255.

Sanders, M.G. (2005). *Building School-Community Partnerships: Collaboration for Student Success.* California: Corwin Press.

Sarpong, D., Meissner, D., Moraes, G.H.S.M.D., & Vismara, S. (2025). The impact of university-industry engagement and the rise of competency transfer partnerships. *The Journal of Technology Transfer*, 1-16.

Schraw, G., & Lehman, S. (2011). Situational interest: A review of the literature and directions for future research. *Educational Psychology Review,* 13(1), 23-52.

Syed, M., Zurbriggen, E.L., Chemers, M.M., Goza, B.K., Bearman, S., Crosby, F.J., Shaw, J.M., Hunter, L., & Morgan, E.M. (2019). The role of self-efficacy and identity in mediating the effects of STEM support experiences. *Analyses of Social Issues and Public Policy,* 19(1), 7-49.

Tobias, S. (1994). Interest, prior knowledge, and learning. *Review of Educational Research,* 64(1), 37-54.

Wang, C.Y., Gao, B.L., & Chen, S.J. (2024). The effects of metacognitive scaffolding of project-based learning environments on students' metacognitive ability and computational thinking. *Education and Information Technologies,* 29(5), 5485-5508.

Vygotsky, L.S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Vol. 86. United States: Harvard University Press.