

Research paper**Building Consensus on the STEMOOV Model in STEM Education:
Insights from a Delphi Study**

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ABSTRACT

The growing demand for STEM professionals highlights the importance of effective STEM education. However, a challenge remains in how STEM education is implemented in practice, as translating STEM principles into meaningful classroom activities continues to be difficult. Integrated STEM approaches address these challenges by linking learning to authentic, interdisciplinary contexts. In this context, the STEMOOV model was developed to operationalise a STEM vision, offering a practical tool to improve STEM education and develop essential skills. This study employed a three-round Delphi method to achieve expert consensus on the STEMOOV model. A panel of academics, educators, and researchers from various countries and educational levels evaluated the model, iteratively revising their opinions on its domains. The study examined which STEM skills are fostered by the model, how it supports students and teachers, its strengths and weaknesses, and its overall relevance for STEM education. The experts agreed that the STEMOOV model effectively fosters skills like collaboration, problem-solving, and critical thinking. Its adaptability to diverse contexts was seen as a strength, though flexible curricula, resources, and teacher training are critical for successful implementation. Overall, the STEMOOV model is a promising tool for integrated STEM education, with potential to engage students and support teachers.

Keywords: integrated STEM, Delphi, STEMOOV, educational model, expert consultation

Over the past decades, rapid scientific and technological innovations have led to a variety of socio-economic and cultural evolutions affecting nearly all aspects of today's society. Because of this, Science, Technology, Engineering, and Mathematics (STEM) have become more crucial in addressing the complex societal and sustainability challenges these evolutions bring, as well as promoting innovation in a knowledge-based economy (Abdulwahed, 2017; Branscum et al., 2020; Yildirim, 2016). In response, educational institutions worldwide have been introducing various initiatives aimed at strengthening STEM education. While a lot of attention has been given to increasing student participation and preparing a competent future workforce, a key challenge remains in how STEM education is implemented in practice (Thibaut et al., 2018). Research shows that translating STEM principles into qualitative classroom practices remains difficult, particularly when it comes to interdisciplinary teaching – the integration of the different STEM disciplines – and the design of authentic learning environments (Kelley & Knowles, 2016; Roehrig et al., 2021). These challenges are observed across different educational contexts and are often shaped by systemic differences in curricula, resource availability or teacher professional development

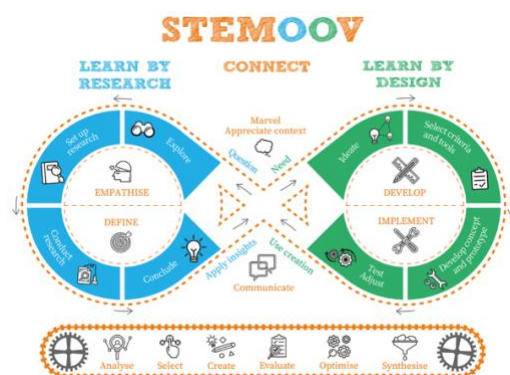
(Madar et al., 2026; Rehman et al., 2025). Regional variations further influence how STEM education is implemented. For example, in Australasia (e.g. Australia and New Zealand), STEM education often emphasises integrated, project-based and inquiry-based approaches, supported by a strong focus on teacher professional development. However, differences in curriculum structures, uneven participation, access to resources, and systemic support can limit effective implementation (Murphy et al., 2019; Bentley et al., 2022; Madar et al., 2026; Marginson et al., 2013; Rehman et al., 2025). Meanwhile, in several European contexts, the integration of STEM disciplines is still developing, although increasing attention is being paid to more integrated approaches (Thibaut et al., 2018). However, STEM education is still perceived as complex, content-driven, and teacher-centred, limiting opportunities for creativity, inquiry, and real-world application (European Commission: Directorate-General for Education, Youth, Sport and Culture, 2015; McDonald, 2016; Thibaut et al., 2018). These findings suggest that the challenge is not only to promote STEM education and student motivation, but also to support teachers in implementing high-quality, integrated STEM practices.

Integrated STEM (iSTEM), where boundaries between two or more STEM domains are crossed and learning takes place in an authentic context, may address these challenges (Barcelona, 2014; Kelley & Knowles, 2016). By linking learning content to authentic problems, iSTEM supports students in developing 21st-century skills such as problem-solving, critical thinking, creativity, and collaboration, all necessary for building a competent future STEM workforce (Han, Kelley & Knowles, 2023; Kelley & Knowles, 2016; Roehrig et al., 2021). Literature on STEM education emphasises that effective STEM learning environments should combine content knowledge with meaningful real-life applications and inquiry-based learning processes (Kelley & Knowles, 2016; Roehrig et al., 2021). Additionally, STEAM frameworks extend iSTEM approaches by incorporating the Arts, thereby highlighting the importance of creativity, design thinking and innovation in STEM learning environments (Al-Mutawah et al., 2022; Bybee & Brown, 2025). By integrating creativity into STEM, both iSTEM and STEAM aim to enhance engagement and problem-solving skills in students. Consequently, STEAM has been gaining popularity in both educational research and practice, for example in Asian educational contexts, as shown in a review by Nguyen and Truong (2025).

Despite these promising perspectives, implementing iSTEM in practice remains challenging. Existing frameworks and models often describe general principles such as interdisciplinary learning, inquiry-based approaches, or real-world problem solving, but teachers report difficulties in translating these principles into concrete classroom practices (Thibaut et al., 2018; Margot & Kettler, 2019; Kelley & Knowles, 2016; Roehrig et al., 2021). This points to a need for practical tools that can support both teachers and students in structuring and enacting integrated STEM learning. Within this context, the Flemish government developed a STEM framework to guide educational institutions and establish a shared vision on STEM (Flemish Government, Education, and Training, 2015). This vision was later translated into the STEMOOV model (Figure 1), a tangible tool and guideline that can be deployed as STEM methodology in teacher training programs and classroom settings.

Figure 1

The STEMOOV model (Adapted from Degrie et al., 2019)



The STEMOOV model aims to support STEM learners, teachers, and educational developers in developing STEM skills and strongly focuses on the integration of Science, Technology, Engineering and Mathematics (Degrie et al., 2019). It can therefore be considered an iSTEM methodology. Given the central role of teaching practices in student learning (Hattie, 2015), tools that support teachers in implementing integrated STEM education, such as the STEMOOV model, may play an important role in improving the quality of STEM education.

Though the STEMOOV model focuses on STEM skills, they lack an unequivocal definition, as they are not distinct (Carnevale, Smith & Melton, 2011). STEM can be considered the roof of a house, including different "rooms," like advanced cognitive skills such as creative and critical thinking and other technical or discipline-related skills. The foundation of the building may include skills needed within daily life, like literacy and numeracy.

Although not specific to STEM, they all support the concept of STEM when considered as a whole (Siekmann & Korbel, 2016). Since there is some conceptual overlap between these so-called 21st-century skills and STEM skills, this study makes no distinction between them.

Despite the model already being implemented in several STEM practices (Universiteit Hasselt, n.d.; Cel iSTEM inkleuren, 2024), its face validity has not yet been established. Given the emphasis on evidence-based practices, it is essential to evaluate the validity and applicability of such models to ensure that they effectively support STEM teaching and learning practices. Therefore, the main aim of this study is to investigate the face validity of the STEMOOV model by obtaining perspectives from STEM education experts and reaching consensus on key aspects of the model and its implementation through a Delphi study. Concretely, the following research questions are addressed:

1. Which STEM skills are stimulated by working with the STEMOOV model?
2. To what extent can the STEMOOV model provide guidance to students and teachers during a STEM project?
3. What are the strengths and weaknesses of the STEMOOV model?
4. To what extent is the STEMOOV model adequate for STEM education?

The STEMOOV model

The STEMOOV model contains five key principles that were described in a systematic literature review carried out by Thibaut et al. (2018). These principles are believed to be the essential components of quality iSTEM education: (1) integration of STEM content, (2) problem-centred learning, (3) cooperative learning, (4) inquiry-based learning, and (5) design-based learning, of which the latter two are implicitly present in the models' name. STEMOOV is an acronym standing for (in Dutch) *STEM (1) Onderzoekend, Ontwerpend en Verbindend leren*, which translates to *learning STEM by Research (4) and Design (5) through Connection*.

The left (blue) part of the STEMOOV model (Figure 1), “*Learn by Research*”, illustrates a research or inquiry cycle comprising four different steps that are always preceded by a “*question*” (written outside the cycle to mark the connection with the broader context) that emerges from an authentic problem, emphasising the problem-centred (2) approach of the model. From the question, the subject is explored, prior STEM knowledge is activated, or new content is introduced, after which the research is conducted, and a conclusion is formulated to answer the question. After completing the research cycle, the insights can be applied. “*Apply insights*” is also written outside of the cycle to illustrate returning the outcomes to the context, communicating them, or using them as a starting point for new research or design.

The right (green) part of the STEMOOV model (Figure 1) is the “*Learn by Design*”-cycle. This process starts with a specific “*need*”, with the word written outside the cycle, as the need for a new design generally originates in a particular context, e.g., daily life or a project. Then, a brainstorming phase takes place: possible solutions to fulfil the need and design options are ideated, whereafter the criteria and tools, necessary to create a solution, are selected. Now a prototype can be developed, tested, and adjusted to deliver a usable and effective, typically tangible solution or creation. The words “*use creation*” are written outside the cycle as well, to highlight the connection between the creation and its use as a response to the original “*need*”.

Both processes are connected through the orange lemniscate. The orange words outside this symbol represent the connection to the surroundings, embedding the process within the original context and making sure to return with the outcomes. This context always holds a significant role within STEM education because of the connection between STEM and real-life challenges (Kelley & Knowles, 2016). “*Marvel*” means to be full of wonder about a real-life or socially relevant problem, while “*appreciate context*” involves the users' values, linked to an authentic context. Additionally, the word “*communicate*” emphasises the importance of interdisciplinarity, cooperation, and teamwork (3) in iSTEM as well as the communication of results and developed creations (Thibaut et al., 2018).

Working with the STEMOOV model is not a linear process with a clear beginning and ending. It is possible to alternate between the two cycles, repeat several steps, or go back and forth again. It is an iterative process challenging higher-order cognitive and practical skills, which are shown in the supporting orange sprocket chain. These skills, some of which are consistent with Bloom's taxonomy (Wilson, 2016), can be applied at any point in the learning cycle of the STEMOOV model. This way, STEM learners from pre-primary to higher education can grow in these skills. Therefore, they symbolise a fundamental (co)growth system and the foundation of the STEMOOV model.

Lastly, the STEMOOV model contains an iterative Design Thinking process involving both diverging and converging steps when navigating through the model. Design Thinking is a form of problem-centred learning that mainly addresses wicked problems. Each stage of Design Thinking alternates between divergent or broadly creative thinking and convergent or critical thinking. During divergent thinking, the goal is to develop the broadest possible understanding of the problem and to generate creative ideas, all of which are considered valuable. STEM learners defer judgment until the convergent phase. Ideas are original, varied, and preferably innovative. Convergent

thinking involves choosing the most promising one(s) from many (research or design) ideas or solutions. Thinking thus converges to a single point. Critical, analytical, and evaluative thinking, concluding, arguing, and working out a concrete solution are important here (Degrie et al., 2019).

All these aspects provide broad applicability for the STEMOOV model, and together with the ownership of the five important key characteristics for iSTEM education, it might prove to be valuable in supporting qualitative STEM education.

METHODS

Delphi design

This study applied the Delphi method. Extensive research already showed the benefits of this method in social and educational sciences (e.g., Branscum et al., 2020; Hallström, Norström & Schönborn, 2023; Munguatosha et al., 2011) where experts' knowledge and experience may provide valuable and reliable insights within, for example, the validation process of a model (Cohen et al., 2000) or the optimisation of school curricula (Osborne et al., 2003). Within science, and more specifically STEM education, the Delphi method proves to be useful as well (Hallström, Norström & Schönborn, 2023). One significant advantage of this method is the possibility of acquiring perspectives from multiple experts regardless of their geographical distance (Sitlington & Coetzer, 2015). In a Delphi study, experts provide structured feedback over multiple rounds to build consensus, refining their ideas through an iterative process that collects both quantitative and qualitative data (Coe et al., 2021; Branscum et al., 2020). This Delphi study encompassed three online rounds, collecting qualitative and quantitative data via Qualtrics and a shared Google Drive document. The expert panel consisted of academics, educational researchers, and (end)users, making this method suitable for establishing the validity of the STEMOOV model at the latter three levels within STEM education

Participants

To ensure a diverse yet purposeful sample, this study aimed to include experts with complementary expertise in STEM education. Experts were eligible to participate if they met at least one of the following criteria: (1) academic and/or practical expertise in STEM education, (2) involvement in STEM-related educational research, or (3) professional experience with STEM in pre-primary, primary, secondary, or higher education settings. Potential experts were identified through multiple channels, including a review of authors in recent STEM education journals, the academic and professional networks of the researchers, LinkedIn, social media calls targeting practitioners, and contacts via STEM initiative websites. The selection process covered a range of educational levels and roles, ensuring that both academic and practical perspectives were represented. Countries with educational systems comparable to Flanders, characterised by similar or higher-than-average instruction time in mathematics and natural sciences in primary or secondary education, were prioritised to form a panel relevant to our context (OECD, 2023). Recruiting the expert panel proved challenging. Experts from various European countries, North America, and Australasia were invited to participate. Of the approximately 30 potential participants contacted, six ultimately agreed to participate, representing all educational levels and roles. Although both male and female experts were invited to participate, the final composition of the expert panel comprised exclusively women. No experts from the Australasia region participated in this study. [Table 1](#) shows an overview of the expert panel.

Table 1

Participant characteristics and expertise

Participant	Title	Location		Years of experience	
Function (previous and/or current)		Experience with educational levels (previous and/or current)			
		Pre-Primary PP	Primary P	Secondary S	Higher H
1	MSc.	Germany		23	
Practice		PP	P	S	H
Teaching in pre-primary and primary school					
Teaching in higher education: pre-service pre-primary,					
primary and secondary school teachers					
STEM project developer (all educational levels)					
Potential user					

Participant	Title	Location		Years of experience	
Function (previous and/or current)		Experience with educational levels (previous and/or current)			
		Pre-Primary PP	Primary P	Secondary S	Higher H
2	PhD-student	California (USA)		8	
Practice Teaching STEM in primary school Teaching a course focusing on the best science teaching practices to pre-service pre-primary and primary school teachers Academic Research: science and STEM education Potential user		X	X	X	
3	Prof. Dr.	Portugal		10	
Practice Teaching science didactics in primary teacher education Academic Research: science and STEM education			X		X
4	Prof. Dr.	Spain		15	
Practice Teaching science didactics to pre-service teachers Supporting teacher professional development focusing on enhancing STEM learning Academic Research: science and STEM education			X	X	X
5	Dr.	Sweden		25	
Practice Teaching STEM in primary education Academic Research: bridging teaching and learning, primarily within STEM education Potential user			X	X	X
6	Prof. Dr.	Minnesota (USA)		17	
Practice Supporting teacher professional development Academic Research: STEM education				X	X

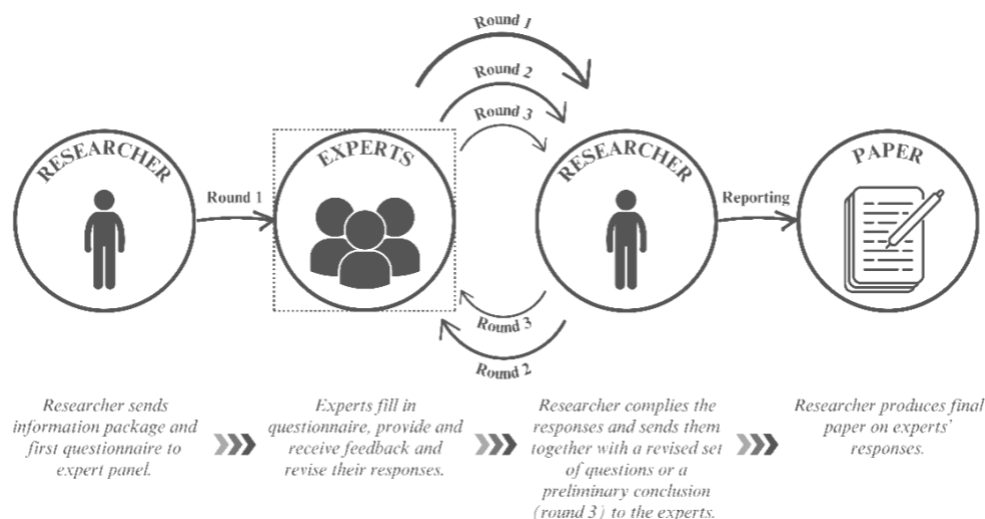
Note. Title= highest degree obtained. MSc.: Master of Science, PhD: Doctor of Philosophy, Dr.: Doctor (holds a PhD), Prof.: Professor (holds a PhD and is an academic instructor at a university or college). Potential users are participants who, in their current function, can apply the model in their practice.

Procedure

This Delphi study encompassed three data-gathering rounds, as visualised in [Figure 2](#).

Figure 2

Overview of the rounds of the Delphi study used within this research



Round 1: Informing and exploring

An online questionnaire was built using Qualtrics, and its clarity and functionality were evaluated by the researchers' research group. At the beginning of the first round, the experts received the questionnaire along with an information package containing a short introduction video of the STEMOOV model, hereafter called the 'STEMOOVIE' (https://www.youtube.com/watch?v=cj9WKai6c_A) and a brochure outlining its theoretical foundations. The questionnaire was designed to evaluate experts' impressions and perceptions of the STEMOOV model and to gather participant characteristics. This questionnaire was requested to be filled in within two weeks.

The questionnaire (Appendix) was organised around the various aspects of the STEMOOV model and included 47 four-point Likert scale statements, ranging from "completely disagree" to "completely agree," alongside two open-ended questions, gauging what other STEM skills might be and might not be fostered by using the STEMOOV model. A four-point scale was chosen to force the experts to take a stance regarding the statements, which is crucial for a Delphi study (Simms et al., 2019). Comment boxes at the end of the questionnaire allowed participants to elaborate on their responses. (Branscum et al., 2017). The Appendix provides an overview of the studied STEMOOV model aspects, including descriptions and their associated research questions.

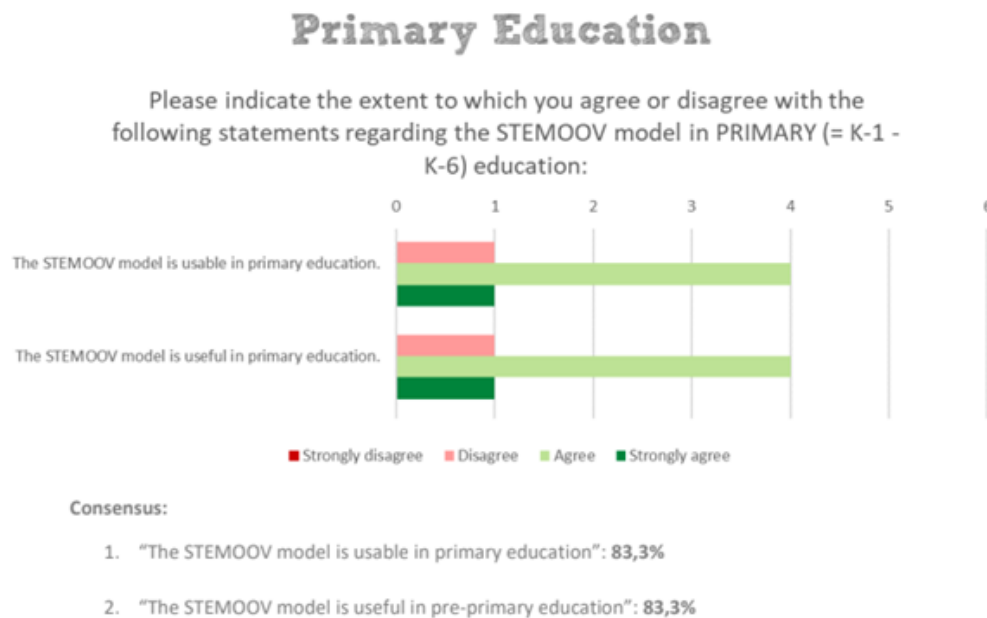
Data resulting from the Likert scale statements were analysed using the Delphi technique. To ascertain whether there is consensus on a particular statement, a predetermined level of consensus was established, as suggested by Manizade & Mason (2011). For this study, since the expert panel consisted of 6 participants, a percentage of 100% consensus was determined, meaning that whenever one or more of the experts "disagreed" or "completely disagreed" with a statement, no consensus was obtained for this particular statement, and the statement was considered not agreed upon by the expert panel. Statements that achieved 100% consensus were considered agreed upon by the expert panel. The statements that were not agreed upon by the expert panel were resubmitted to round 2 of the study. The raw qualitative data were listed in a narrative document and were sent, together with the other results from this round to the experts in round 2, where they were instructed to elaborate on their responses.

Round 2: Iteration and refining

Experts were asked to elaborate on their responses given to the statements that did not meet 100% consensus in round 1. This was not obligatory; however, the experts that answered 'disagree' or 'strongly disagree' were encouraged to elaborate to better understand their perspectives. The experts were also given additional four-point Likert scale statements regarding STEM skills that were brought up within the open questions in round 1. Lastly, the experts were allowed to comment on each other's feedback, also provided by the comment boxes in round 1. The qualitative data emerging from the elaborated responses were inductively and thematically analysed. Thematic analysis was performed following Coe et al. (2021) and Cohen et al. (2000), involving a three-step coding process in which concepts were first labelled at code level, then organised into categories, and finally clustered into themes related to the research questions. A 22-page document summarising the identified themes and all Likert-scale responses from rounds 1 and 2, presented both graphically and in text (Figure 3), was shared with the expert panel via Google Drive in round 3. From these results, provisional answers to the research questions were formulated.

Figure 3

Example of how the responses to a Likert scale statement are reported back to the expert panel in the summary document



Round 3: Final consensus

The final round aimed to achieve consensus on the conclusion. After sharing the Google Drive document, the experts could provide semantic feedback to nuance the results or comments, modify some words, or provide additional feedback. By using Google Drive, the experts had the opportunity to directly comment on each other and discuss topics. Lastly, they were asked to give their explicit consent to the conclusion. All six experts consented, provided their comments and feedback were considered for the final conclusion, as reported in this paper.

RESULTS

The questionnaire used in this study was structured around the components of the STEMOOV model. Specific items from the questionnaire were utilised to address the research questions. The items used to answer each research question are presented in the [Appendix](#). The results are structured and presented in alignment with the research questions.

RQ 1: Which STEM skills are stimulated by working with the STEMOOV model?

Of the initially targeted STEM skills that the STEMOOV model aims to foster, all six experts consented on the skills "collaboration" and "communication". Five of them believed this was also the case for the skills "creativity", "critical thinking" and "problem-solving". The least consensus was reached for "computational thinking". Three of the experts found this skill to be potentially stimulated by the STEMOOV model ([Table 2](#)). Of the additional skills listed by the experts, of which some are not, by definition, STEM skills, all experts agreed that the STEMOOV model could foster the following skills: "evaluation," "flexibility," and "innovation." The least supported skill was "learning non-applicable theory," which was brought up by one expert and was supported by only two other experts.

At the end of the questionnaire, one expert stressed:

"Many of these skills could be developed within the model—but again, it depends on implementation and details that are beyond the scope of the model."

Two other experts emphasised the need for empirical evidence to establish the possibilities of the STEMOOV model in developing the above-mentioned skills. One of them explained:

"We can think that the model offers the opportunity to work on these kinds of skills, but we would need empirical evidence."

Table 2*Results of the Likert scale questions regarding the (STEM) skills*

<i>Skill</i>	# experts answering				<i>Consensus (=6/6)</i>
	<i>'strongly disagree'</i>	<i>'disagree'</i>	<i>'agree'</i>	<i>'strongly agree'</i>	
Collaboration	0	0	4	2	<u>6/6</u>
Communication	0	0	4	2	<u>6/6</u>
Developing explanation*	0	0	3	3	<u>6/6</u>
Decision making*	0	0	2	4	<u>6/6</u>
Design thinking*	0	0	3	3	<u>6/6</u>
Evaluation*	0	0	5	1	<u>6/6</u>
Flexibility*	0	0	3	3	<u>6/6</u>
Innovation*	0	0	3	3	<u>6/6</u>
Optimising*	0	0	3	3	<u>6/6</u>
Adaptability*	1	0	3	2	5/6
Argumentation*	0	1	3	2	5/6
Creativity	0	1	1	4	5/6
Critical thinking	0	1	3	2	5/6
Curiosity*	0	1	1	4	5/6
Empathy*	0	1	2	3	5/6
Inclusiveness*	0	1	3	2	5/6
Modelling*	0	1	3	2	5/6
Self-regulation	0	1	3	2	5/6
Teamwork*	0	1	1	4	5/6
Problem scoping*	0	1	2	3	5/6
Problem solving	0	1	1	4	5/6
Self-agency*	0	1	4	1	5/6
Systemic thinking*	0	1	3	2	5/6
Taking initiative*	0	1	4	1	5/6
Attention to detail*	1	1	4	0	4/6
Considering trade-offs*	1	1	2	2	4/6
Customer Orientation*	1	1	3	1	4/6
Mathematical reasoning*	0	2	3	1	4/6
Precision*	1	1	4	0	4/6

<i>Skill</i>	# experts answering				<i>Consensus (=6/6)</i>
	<i>‘strongly disagree’</i>	<i>‘disagree’</i>	<i>‘agree’</i>	<i>‘strongly agree’</i>	
Time management*	0	2	4	0	4/6
Usability*	1	1	2	2	4/6
Computational thinking	0	3	2	1	3/6
Learning non-applicable theory*	2	1	3	0	3/6

Note. Skills marked with* are skills proposed by the experts in the questionnaire. When all experts answer ‘agree’ or ‘strongly agree’, a consensus for that skill is reached (shown in bold).

RQ 2: To what extent can the STEMOOV model provide guidance to students and teachers during a STEM project?

To answer this research question, results of the Likert scale statements of the questionnaire’s components, “1. The Lemniscate Process” up to and including “4. Connect,” were consulted ([Appendix](#)). Different aspects of the model that might provide guidance through a STEM project were identified and agreed upon by the expert team. More specifically:

- the Lemniscate Process, which provides a logical structure to STEM education and encourages flexibility and connection between the Design and Research cycle (1.1 & 4.1);
- the Learn by Research Cycle, which comprises a complete and logical structure of a research process with a clear visualisation of the different steps (1a1-1a3);
- the Learn by Design Cycle, which comprises a complete and logical structure of a design process with a clear visualisation of the different steps (1b1-1b3);
- the process of convergent and divergent thinking that is embedded in the model (2.3);
- the connection with the higher-order cognitive and practical skills (4.8).

All other statements were agreed upon by five out of six experts. Some statements received specific feedback. For example, the statement “The Lemniscate Process encourages flexibility in going through the different cycles” raised the following remark:

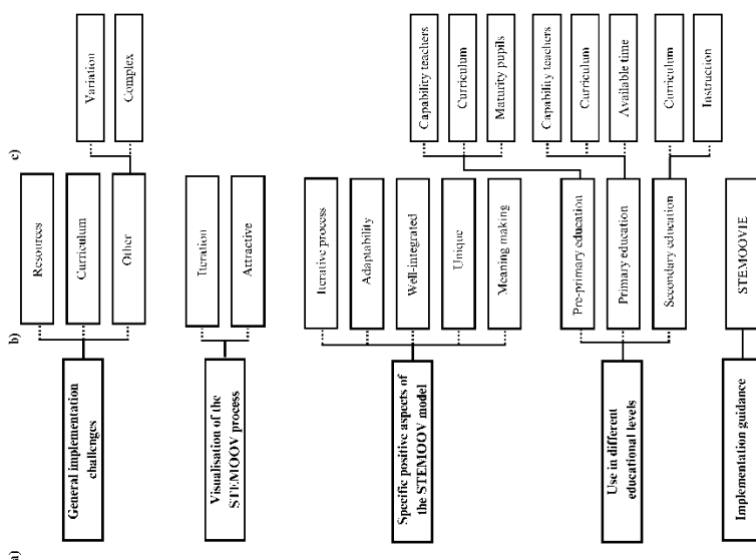
“It indicates potential connections, but when thinking about how to implement the model in real teaching practices, teachers or educators might wonder to what extent it is necessary to go through all the stages or if it would necessarily require different cycles or iterations.”

Lastly, one expert wrote as an additional remark:

“Very often we understand ‘providing guidance’ as giving instructions or recommendations...I would say that the model provides a powerful framework or structure to articulate an interesting learning process for addressing STEM projects.”

RQ 3: What are the strengths and weaknesses of the STEMOOV model?

Thematic analysis of the extra remarks provided by the experts identified several themes, revealing both strengths and potential challenges of the STEMOOV model. The themes relate to general implementation challenges, the visualisation of the STEMOOV process, specific positive aspects of the STEMOOV model, its use across different educational levels, and implementation guidance. This research question specifically focused on the qualitative feedback provided by the respondents. To contextualise and further substantiate the identified themes, selected Likert scale items from components 1 through 4 were used where relevant. The results are structured according to the themes and subthemes presented in [Figure 4](#). Quotes were included to illustrate the diversity of expert opinions or, in cases of clear agreement, to provide examples of consensus.

Figure 4*Themes and codes identified from the thematic analysis of the experts' additional remarks*

Note: a) general theme, b) category or code level, c) code level

General implementation challenges

The expert panel brought up several challenges related to the implementation of the STEMOOV model in practice. These mainly concerned the availability of resources, the structure and flexibility of the curriculum, and other contextual factors. More specifically, three experts highlighted the importance of appropriate infrastructure and trained teachers. They stated that implementation may depend on factors such as personnel, class sizes, availability of materials, and the willingness of educators to be open-minded and to collaborate.

Another mentioned factor was the school curriculum. Two experts noted that the way courses are structured, the flexibility within the curriculum, and the available time to implement the STEMOOV model may affect its feasibility. One expert explicitly stressed the importance of flexibility:

“Flexibility in science curriculums is in dire need across the globe. Rigidity in content and information is taking a toll on students and their success and motivation.”

Other remarks related to variation and complexity. For example, one expert noted that the STEMOOV model is not a “one size fits all” model, suggesting that its implementation may vary depending on the educational context. Lastly, two experts indicated that the model may initially appear complex, which could hinder understanding.

Visualisation of the STEMOOV process

Several experts positively evaluated the visualisation of the STEMOOV process. More specifically, the visual representation of the iterative character of the model was considered clear, according to the Likert scale results, where five experts agreed that the possibility for iterative use is clearly visualised in the model. Furthermore, two experts found the visual representation of the STEMOOV model to be attractive.

Specific positive aspects of the STEMOOV model

The expert panel highlighted several strengths of the STEMOOV model. For example, two experts emphasised the model’s iterative process as an important strength and explained that it supports reflection and allows users to revisit earlier stages of the process. One expert stated:

“I especially like the fact that it is an iterative process that allows for reflection, where no matter where you are in the process, you can always go back and check findings or include other resources or thoughts you may not have included in the research design.”

Another expert added that the iterative process might also prepare students to deal with complex situations. This was highlighted by two other experts in the summary document, emphasising the strength of the iterative process. Additionally, it was mentioned by two experts that, since previous knowledge and student-generated ideas play an important role while using the STEMOOV model, it might stimulate a meaning-making process in students and prepare them to deal with complex situations. Furthermore, the model was specifically referred to as “attractive,” “unique,” and “well-integrated.” The Likert scale questions further highlighted other strengths of the STEMOOV model. For example, five experts viewed the design thinking process as added value to the model

while clearly seeing how it is incorporated into the model. Finally, the expert panel unanimously agreed that the STEMOOV model supports interdisciplinarity across STEM domains.

Use in different educational levels

The experts discussed the potential use of the STEMOOV model across different educational levels, with most remarks focusing on primary and pre-primary education. There was disagreement regarding teachers' capability to deliver STEM across these educational levels. One expert noted:

"I see its utility for curriculum writing and guiding instruction in middle and high school grades. Harder in primary education, where so little time is available for science or STEM, and teachers are less well prepared."

In contrast, another expert responded:

"Our experience working with teachers of different educational levels is that usually preschool and primary school teachers feel more comfortable than secondary school teachers when working with integrative approaches."

Similar barriers were mentioned for pre-primary education. One expert suggested that pupils might struggle to engage with the model because the curriculum in their country is largely based on play and spontaneous topics. However, another expert described this as an opportunity rather than a barrier, as she explains that it gives more freedom this way. Additionally, one expert raised concerns that pupils of this educational level might lack a certain level of cognitive maturity to use the STEMOOV model (higher-order skills that require abstract thinking might be too difficult), but this statement was contradicted by two other experts that stated that young children are capable of doing STEM as long as the complexity is tailored to their level and STEM education is started early enough, focusing on skills rather than traditional content, and if proper guidance is available. They stated that the STEMOOV model might be able to promote this.

For secondary and higher education, all experts agreed that the STEMOOV model can be useful and usable in secondary and higher education. No other comments were given regarding the use of the model in secondary and higher education.

Implementation guidance

Two experts emphasised the importance of providing guidance when introducing the STEMOOV model to educators. In this context, the STEMOOVIE was mentioned as a useful supporting tool that can help users understand how the model works in practice and promotes familiarisation with the different elements of the model.

RQ 4: To what extent is the STEMOOV model adequate for STEM education?

To address this research question, responses to the Likert scale statements related to aspect "0. The complete STEMOOV model" were analysed. Notably, one of these questions directly aligned with the research question itself. All experts agreed with this statement as well as the statements that the model supports STEM curricula, that it strengthens interdisciplinarity between the different STEM domains, and that it is useful compared to other STEM education approaches, despite not providing specific examples of such methods.

When discussing the effectiveness of the model compared to other STEM education approaches, five experts initially agreed on this statement. However, two experts later changed their opinions: one expert initially agreed but then disagreed, while the other shifted from disagreement to agreement. They explained that their uncertainty stemmed from not knowing which approach the model should be compared to. However, no comparative approach was suggested by any of the experts. In addition, one expert elaborated that empirical evidence supporting the usability and benefits of the model is necessary to accurately assess these statements.

DISCUSSION

This Delphi study explored the STEMOOV model's potential in STEM education by identifying possibly stimulated STEM skills, evaluating its guidance for students and teachers, and assessing its strengths, weaknesses, and overall adequacy. By involving iSTEM experts with diverse backgrounds, a broad perspective on the model across educational contexts was obtained. While the OECD report (2023) highlights some similarities across participants' educational systems, local variations remain, including STEM integration into curricula, availability of material and technological resources, teacher professional development, and systemic support for integrated STEM approaches (Bybee, 2013; Marginson et al., 2013). These differences suggest that interpretations of the STEMOOV model are context dependent. Furthermore, since the expert panel in this study did not include representatives from all global regions, such as Australasia or developing contexts, some context-specific perspectives may not have been fully captured, and the STEMOOV models' applicability in these contexts remains speculative.

Although the Delphi panel reached partial consensus on several aspects of the STEMOOV model, these findings should be interpreted cautiously, as they may partly reflect the similarities among the educational systems

represented by the experts. Across regions, STEM education faces diverse challenges in participation, motivation, and pedagogical approaches. In Australasia, for instance, curriculum structures, pedagogical approaches, and teacher professional development might vary substantially compared to the participants' educational systems, underscoring the need to adapt models like STEMOOV to local contexts to ensure effective implementation and meaningful impact on student learning (Madar et al., 2026; Marginson et al., 2013; Rehman et al., 2025). Future research could benefit from including experts representing a broader range of educational contexts and pedagogical traditions. This would provide a more complete picture of how models such as STEMOOV could be applied across different contexts. Overall, these considerations reinforce that the results are context-sensitive rather than universally generalisable and highlight the importance of tailoring STEM interventions to local educational, curricular, and professional circumstances.

A further limitation relates to the relatively small and specialised expert panel. While Delphi studies vary considerably in panel size, and expert diversity, expertise and commitment are often considered more important than size (Bloor et al., 2013; Iqbal & Pison-Young, 2009; Ogbeifun et al., 2016), the limited number of participants constrained the use of statistical techniques to formally establish consensus. Therefore, this study is better characterised as a qualitative, exploratory Delphi approach, focusing on patterns of agreement and disagreement, as well as the iterative refinement of expert perspectives across rounds, rather than formal consensus measures. This aligns with contemporary views of the Delphi method as a flexible and evolving methodology (Hasson et al., 2025). At the same time, working with a smaller panel enables a more in-depth exploration of differing viewpoints and underlying reasoning (Vogel et al., 2019).

The findings indicate that the STEMOOV model has the potential to support the development of key skills such as flexibility, curiosity, and creativity. These are particularly relevant given the persistent perception of STEM as rigid and content-driven (McDonald, 2016), and may contribute to increasing student motivation (Kelley & Knowles, 2016). In addition, the model was perceived as supporting meaning-making processes, potentially helping to bridge the gap between the complexity of real-world problems and STEM education. At the same time, variations in how experts conceptualised STEM skills highlight the lack of a shared definition in the literature (Carnevale, Smith & Melton, 2011), which may have influenced the responses. Future research could address this by explicitly defining STEM skills or by exploring how experts conceptualise them.

Although the study included questions covering all educational levels equally, more comments arose regarding STEM or the STEMOOV model in primary education. This likely reflects the greater number of experts with experience at this level or that STEM at the primary educational level sparked more discussion among the expert panel. At the same time, few remarks were made regarding secondary education. This can be considered a limitation of the study. Implementing the STEMOOV model in secondary education may pose additional challenges due to differences in curricula or assessment systems. Moreover, as the STEMOOV model was developed within a Western educational context, its implementation may differ in other educational systems. Although it is difficult to predict how these differences might manifest in practice, exploring them represents an interesting avenue for future research. Future research could also investigate how the STEMOOV model might be used as a tool to support the evaluation of learning content across different educational levels. In some educational contexts, such as Flanders, recent curriculum developments have introduced specific multidisciplinary STEM subjects in secondary education, which require more integrated forms of assessment. In this regard, it would be interesting to explore how the STEMOOV model could support and structure the evaluation of integrated STEM learning in practice. This seems particularly relevant given that some experts in this study already pointed to challenges related to implementation and assessment.

Further, a significant point of debate between the experts was whether pupils in pre-primary education possess sufficient cognitive maturity to engage in STEM activities or to utilise the STEMOOV model. In this case, both perspectives hold elements of truth. An empirical exploratory study published by Lloyd et al. in 2018 reported that children aged zero to three, when exposed to STEM activities, demonstrated behaviors and an interest in various events that could be viewed as an understanding of scientific ideas. Furthermore, young children (age four to five) have a natural curiosity and the ability to think critically and reason logically (FitzGibbon et al., 2019). However, certain complex cognitive skills such as abstract thinking may not be fully developed in young children (Dumontheil, 2014). Research showed that introducing STEM activities to young children enhances these skills (Agrawal & Sureka, 2017), suggesting the value of the STEMOOV model in STEM education for this educational level, potentially with adjustments to its perceived complexity.

Furthermore, the experts noted that the model can be challenging to implement due to limited time and flexibility within school curricula. However, this is more a limitation of the educational system than of the STEMOOV model itself. This could also clarify the experts' remark that teachers in primary school are sometimes less equipped to teach STEM education, which can result in a lack of confidence to do so. Thus, when considering the implementation of the STEMOOV model across different educational levels, it is important to take into account that teachers at different levels often have distinct pedagogical and professional backgrounds. The results

of this study suggest that primary school teachers may be more accustomed to integrating multiple learning domains within their teaching practices while at the same time potentially having less explicit STEM content knowledge. This is consistent with the findings of the review by Yoon et al. (2025). Such differences may lead to challenges when implementing the STEMOOV model and should therefore be taken into account.

While the expert comments offered valuable insights into the strengths and weaknesses of the STEMOOV model, they were not sufficient to provide an in-depth understanding of some aspects of their responses. For example, no specific comparative approach was suggested to evaluate the STEMOOV model against other frameworks. Furthermore, the observation that "the STEMOOV model is not one size fits all" indicates a need for further exploration into how the model can be adapted to diverse contexts.

We recognise the importance of gaining a deeper understanding of these nuances. Conducting in-depth interviews with experts and practitioners would allow us to better grasp the underlying reasoning behind their feedback and to explore practical challenges in greater detail. By offering professional development training, teachers could be empowered to confidently integrate STEM activities into their classrooms, strengthening the model's applicability and ultimately maximising its impact on early integrated STEM (iSTEM) education.

While the findings highlight several promising aspects of the model, they also emphasise the importance of further research into its practical implementation. Future research should therefore focus on empirical implementation studies and investigations of concrete classroom practices to examine how the STEMOOV model functions in real educational contexts. Such studies could also provide further insight into how the model can be adapted to different educational systems, pedagogical traditions, STEM approaches internationally and thematic applications such as education for sustainable development or digital literacy. In addition, combining implementation studies with in-depth interviews involving teachers, practitioners, and experts could contribute to a better understanding of the practical challenges, training needs, and contextual adaptations that may be required for the effective use of the STEMOOV model across different educational levels.

CONCLUSION

This Delphi study aimed to investigate the potential of the STEMOOV model to enhance STEM education through an integrated approach. The expert panel indicated that the STEMOOV model can support the development of key STEM skills such as collaboration, problem-solving, and creativity, alongside broader competencies like flexibility and curiosity. In particular, features such as the Lemniscate Process and the emphasis on real-life connections were considered valuable for guiding STEM projects, fostering reflection, and supporting meaning-making in students. The model appears adaptable to diverse classroom settings; however, its effective implementation depends on factors such as curricular flexibility, availability of resources, and teacher preparation or professionalisation. For pre-primary and primary education, additional guidance may be needed to align the model with the developmental needs of younger learners. Overall, the findings suggest that the STEMOOV model has potential as an integrated STEM approach that supports interdisciplinarity and enriches STEM education across educational levels, although its implementation may differ depending on the educational context.

List of abbreviations

STEM: Science, Technology, Engineering, Mathematics

iSTEM: integrated Science, Technology, Engineering, Mathematics

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Ethical statement

All participants provided informed consent electronically prior to their participation in the study.

Competing interests

The authors declare no competing interests.

Author contributions

M.V. was responsible for all aspects of the research and manuscript preparation. I.E. contributed to the research concept and design, data collection, analysis and interpretation, as well as the writing and final approval of the article. E.E. contributed to the research concept and design, the critical revision of the article, and its final approval. S.D., K.D., and I.S. contributed to the critical revision of the article and its final approval. T.K. contributed to the research concept and design, the critical revision of the article, and its final approval.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

AI disclosure

We acknowledge the use of ChatGPT to suggest and revise the structure of the discussion and results section (prompt e.g.: “my discussion contains the following key points ..., what would be a logical structure?”) or help shorten small sections of the manuscript when the word limit was exceeded. DeepL was used as a translation tool, and Quillbot was used to assist in paraphrasing and refining selected parts of the text.

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APPENDIX

Aspect	Description
0. The complete STEMOOV model	<i>The overall impression of the STEMOOV model. The questions address the model's suitability, support, interdisciplinary nature, usability, and effectiveness in different educational levels.</i>
	Questionnaire statements RQ
	0.1 The STEMOOV model is adequate for STEM education. 4
	0.2 The STEMOOV model supports STEM curricula. 4
	0.3 The STEMOOV model strengthens interdisciplinarity between the different STEM domains (Science, Technology, Engineering, Mathematics). 4
	0.4 The STEMOOV model is useful compared to other STEM education approaches. 4
	0.5 The STEMOOV model is effective compared to other STEM education approaches. 4
1. The Lemniscate Process	<i>This aspect contains three subaspects: Learn by Research Cycle, Learn by Design Cycle and Iterative use of the model.</i>
	Questionnaire statements RQ
	1.1 The Lemniscate Process provides a logical structure to STEM education. 2,3
	1.2 The Lemniscate Process gives a clear visualisation of a STEM education process. 2,3
	1.3 The Lemniscate Process is of added value to the STEMOOV model. 2,3
1a. Learn by Research Cycle	<i>This subaspect assesses the structure and visualisation of the research process within the Lemniscate Process. The questions focus on the logical structure, completeness of the steps, and clarity of the symbols.</i>
	Questionnaire statements RQ
	1a1 The Learn by Research Cycle provides a logical structure of a research process. 2,3
	1a2 The different steps of the Learn by Research Cycle comprise a complete research process. 2,3
	1a3 The symbols used in the Learn by Research Cycle give a clear visualisation of the corresponding steps in a research process. 2,3
	1a4 The Learn by Research Cycle is of added value to the STEMOOV model. 2,3

1b. Learn by Design Cycle	<i>This subaspect evaluates the same items as subdomain 1a, but for the design process within the Lemniscate Process.</i>	
	Questionnaire statements	RQ
	1b1 The Learn by Design Cycle provides a logical structure of a design process.	2,3
	1b2 The different steps of the Learn by Design Cycle comprise a complete design process.	2,3
	1b3 The symbols used in the Learn by Design Cycle give a clear visualisation of the corresponding steps in a design process.	2,3
	1b4 The Learn by Design Cycle is of added value to the STEMOOV model.	2,3
1c. Iterative use of the model	<i>This subaspect assesses the potential for iterative use and its visualisation within the Lemniscate Process.</i>	
	Questionnaire statements	RQ
	1c1 The Lemniscate Process highlights the possibility to go through a process wherein steps from the design and the research cycle are flexibly alternated.	2,3
	1c2 The possibility for iterative use is clearly visualised in the Lemniscate Process.	2,3
2. The Design Thinking Process	<i>This aspect evaluates the importance and integration of the Design Thinking Process within the STEMOOV model, as well as the value of divergent and convergent thinking.</i>	
	Questionnaire statements	RQ
	2.1 The Design Thinking Process is of added value to the STEMOOV model.	2,3
	2.2 It is clear how the Design Thinking Process is incorporated into the STEMOOV model.	2,3
	2.3 The process of divergent and convergent thinking is of added value in the STEMOOV model.	2,3
3. Higher-order cognitive and practical skills	<i>This aspect assesses the extent to which the skills illustrated in the sprocket chain of the model are representative of the skills required in STEM education and the effectiveness of the model in promoting these skills.</i>	
	Questionnaire statements	RQ
	3.1 The higher-order cognitive and practical skills shown in the STEMOOV model are a good representation of the skills needed in STEM education.	2,3
	3.2 Using the STEMOOV model in STEM education invokes the skills illustrated in the sprocket chain.	2,3
	3.3 The representation of the higher-order cognitive and practical skills in the sprocket chain are of added value to the STEMOOV model.	2,3
4. Connect	<i>This aspect assesses the various methods by which the STEMOOV model facilitates connections, e.g. between the different domains and with real-world contexts as well as the general public.</i>	
	Questionnaire statements	RQ
	4.1 The Lemniscate Process encourages flexibility in going through the different cycles.	2,3
	4.2 The Lemniscate Process encourages connection between research and design processes.	2,3
	4.3 Working with the STEMOOV model encourages connection between all the different STEM domains (Science, Technology, Engineering, Mathematics).	2,3
	4.4 Working with the STEMOOV model connects STEM education with real-life contexts and situations.	2,3
	4.5 Working with the STEMOOV model fosters connection with the broader public through communication.	2,3
	4.6 Working with the STEMOOV model encourages connection between the interdisciplinary team of users.	2,3

	4.7 The STEMOOV model connects the Design Thinking process with the Lemniscate Process.	2,3
	4.8 The STEMOOV model connects the higher-order cognitive and practical skills (illustrated in the sprocket chain) with the Lemniscate Process.	2,3
5. STEM skills	<i>This domain assesses the particular STEM skills that are and are not fostered by the STEMOOV model.</i>	
	Questionnaire statements	RQ
	5.1 Working with the STEMOOV model stimulates the development of following STEM skill: problem-solving.	1
	5.2 Working with the STEMOOV model stimulates the development of following STEM skill: critical thinking.	1
	5.3 Working with the STEMOOV model stimulates the development of following STEM skill: collaboration.	1
	5.4 Working with the STEMOOV model stimulates the development of following STEM skill: self-regulation.	1
	5.5 Working with the STEMOOV model stimulates the development of following STEM skill: communication.	1
	5.6 Working with the STEMOOV model stimulates the development of following STEM skill: creativity.	1
	5.7 Working with the STEMOOV model stimulates the development of following STEM skill: computational thinking.	1
	5.8 What other STEM skills are stimulated by working with the STEMOOV model?	1
	5.9 What other STEM skills are not stimulated by working with the STEMOOV model?	1
6. Differentiation in educational levels	<i>This aspect evaluates the STEMOOV model's applicability and use at several educational levels, ranging from pre-primary to higher education.</i>	
	Questionnaire statements	RQ
	6.1 The STEMOOV model is usable in pre-primary education.	3
	6.2 The STEMOOV model is useful in pre-primary education.	3
	6.3 The STEMOOV model is usable in primary education.	3
	6.4 The STEMOOV model is useful in primary education.	3
	6.5 The STEMOOV model is usable in secondary education.	3
	6.6 The STEMOOV model is useful in secondary education.	3
	6.7 The STEMOOV model is usable in higher education.	3
	6.8 The STEMOOV model is useful in higher education.	3