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LEARNING SKILLS ACQUIRED AT SCHOOL FOR STEM STUDIES AT THE UNIVERSITY

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Abstract

In order to acquire science, it is necessary to perform hands-on activities, make experiments and scientific inquiry with the obtained data, to be able to evaluate critically and understand the scientific concepts, as well as to collaborate and communicate. STEM learning promotes inquiring minds, logical reasoning, and communication and collaboration skills. Studying science at the university, students need both hard – cognitive and subject specific skills and soft – interpersonal and intrapersonal skills. The aim of the study was to clarify the appropriateness/usefulness of the learning skills acquired at school for STEM studies at the university. The study consisted of two parts: a systematic review of Web of Science and SCOPUS databases and surveys of 242 first-year science students of the University of Latvia about the learning skills acquired at school performed in 2018–2020. The qualitative data processing program AQUAD was used for processing data obtained from students' survey. Data coding was performed according to the code system developed specifically for this purpose. The qualitative data was transferred into a quantitative format, based on relations between students' statements, and linkages among codes were created. The study allowed concluding that cognitive, interpersonal and intrapersonal skills acquired at school are intrinsic learning skills during the first study year in higher education. There are no principal differences in the evaluation of hard and soft skills in the systematic review and students' responses that proves the appropriateness/usefulness of the 21st-century learning skills acquired at school for science studies at the university.

Keywords: *learning skills, STEM education, first-year university students*

Introduction

The need for STEM knowledge and skills in today's socio-economic context to meet the demands of the global economy and the challenges of an increasingly threatened environment is becoming ever more pressing (Tytler, 2020; Villán-Vallejo et al., 2022). STEM learning promotes inquiring minds, logical reasoning, and collaboration skills. In science education, it is important to be able to use epistemological knowledge, procedural knowledge, and technical knowledge. This means knowing science content, integrating it into other subjects, interpreting information, engaging in research, reasoning logically and using real-life examples to solve problems (Johnson et al., 2022; Ng, 2019).

The school reform in Latvia, too, envisages the transfer to competence-based learning content that creates changes not only in the teaching/learning content but also in the process of how learning and teaching take place (Andersone, 2017). The competence-based teaching/learning approach foresees the development of transversal skills that incorporate significant cognitive, affective and social aspects of the learner's actions. The transversal skills to be developed include critical thinking and problem solving, innovation and entrepreneurship, self-directed learning, collaboration, civic participation, and digital skills (Skola 2030, 2020).

There is not a single approach to defining the 21st-century skills. Frequently, such terms as "life skills", "soft skills", "transversal skills", "generic skills", "critical skills" and "digital skills" are considered as synonyms of 21st-century skills. Skills are classified in several different

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ways, for example, 4Cs – Critical thinking, Communication, Collaboration and Creativity, 3Rs – Reading, Writing and Arithmetic (Joynes et al., 2019). Researchers offer the division of skills into four groups: 1) ways of thinking – creativity and innovation; critical thinking, problem solving, decision making; learning to learn, metacognition; 2) ways of working – communication; collaboration (teamwork); 3) tools for working – information literacy; ICT literacy; 4) living in the world – local and global citizenship; life and career; personal and social responsibility, including cultural awareness and competence (Binkley et al., 2012). The OECD Learning Compass 2030 (2019) has described three types of skills: cognitive and metacognitive skills; social and emotional skills; and practical and physical skills. Learning skills can be divided also into two large groups: hard and soft skills. Hard skills are considered to be the cognitive learning skills that are needed for the acquisition of the subject content. Their acquisition is best described by "*You have learned, now go and do!*" (Henville, 2012, p. 43). Hard skills could be described in more detail from two aspects, i.e., both in the general and specific context in which these skills are applied (Putra et al., 2020). Other researchers call general skills basic skills (Sen et al., 2018) referring to such skills as the skills for reading, writing and arithmetic operations. Geisinger (2016) admitted that 21st-century skills definitely should exceed the reading, writing and arithmetic level. At the same time problem solving, critical and creative thinking, learning, and managing complex situations also could be added to general skills (Sen et al., 2018). As indicated by Beers (2011), the STEM curriculum, in particular, incorporates creativity and critical thinking from the "4 Cs" of 21st-century skills. This means that in science it is not sufficient to use only the above-mentioned key skills in describing and analysing the empirical data. There is also a need to apply in practice the theoretical knowledge of the subject in problem solving, for logical thinking when performing critical evaluation and understanding the scientific principles as well as the ability to discuss and present (English, 2017; Fan & Ritz, 2014). The specific STEM skills are connected with domains of science subjects and usually are acquired through education and transferred to real life and practice (Sen et al., 2018). Thus, reading, writing and numeracy literacy as well as problem-solving, logical and critical thinking and creativity could be considered as general skills in science, but the STEM discipline specific skills would be: experimentation, observation, inquiry, engineer-technical skills, probably adding complex real-world problem-solving skills in the multidisciplinary approach. Similarly, it is possible to argue on collaboration – whether it is a generic skill or a subject specific skill because the learner can participate in collaboration more effectively if he has the content knowledge. Without such knowledge, the learner acts more as an observer than a true collaborator. However, collaboration belongs to soft skills as an interpersonal skill along with communication and leadership (Evans, 2020).

Soft skills indicate the personal transversal skills, e.g., social, presentation and communication skills, friendliness, and the ability to work in a team and other personal qualities that describe relations among people (Cimatti, 2016). They can be divided into intrapersonal and interpersonal learning skills. Intrapersonal skills involve a group of metacognitive skills: self-management, time management, self-development, self-regulation, adaptability, and executive functioning. Interpersonal skills consist of complex communication, social skills including collaboration, teamwork, cultural sensitivity, and dealing with diversity (Geisinger, 2016). Traditionally, soft skills are considered the complements of hard skills in order to perform particular tasks or activities (Cimatti, 2016).

Based on the classification of learning competencies developed by Soland, Hamilton and Stecher (2013) and supplementing it with ideas of other researchers mentioned above on learning skills (English, 2017; Fan & Ritz, 2014; Geisinger, 2016; Putra et al., 2020; Siekmann & Korbel, 2016), the authors made a summary of the classification of learning skills (Table 1) which was applied in the study.

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Table 1
Summary on the Classification of Learning Skills

Hard skills	Soft skills	
Cognitive learning skills	**Interpersonal learning skills**	**Intrapersonal learning skills**
General skills: reading, writing, remembering, numbering, critical and higher-order thinking, problem-solving, creativity STEM discipline specific skills: experimentation, observation, scientific inquiry, engineering technology skills	Communication Collaboration Leadership Teamwork Dealing with diversity	Learning how to learn (metacognition) Intrinsic motivation Grit Adaptation (adaptability) Self-development Self-respect (esteem) Self-management Self-regulation (direction) Time management

Research Aim and Research Questions

Summarising theoretical ideas resulted in raising a question, namely, what Latvian school students' learning skills are in comparison with the data of the above-mentioned studies. As proved by recent publications, 21st-century skills are diverse, including the skills necessary for STEM acquisition (English, 2017; Fan & Ritz, 2014). School should develop these skills in their diversity and many-sidedness so that students are ready to continue their education in higher education institution. The aim of the study was to clarify the appropriateness/usefulness of the learning skills acquired at school for STEM studies at the university.
Two research questions were put forward:
1. What learning skills are necessary to be successful in STEM education?
2. How do the first-year students of the University of Latvia studying STEM evaluate their learning skills acquired at school?

Research Methodology

General Background

Learning skills acquired at school is a vital precondition for a successful study process; however, often in the transition from school to university, there is a need for adaptation and additional development of skills (Ellen et al., 2010; Stone, 2021), therefore it was important to find out what skills students had acquired at school and which of them they considered more important. In order to clarify that, the qualitative research method was chosen, which allows researchers to obtain individualized and detailed data, promotes a more flexible involvement of participants and offers a holistic look at the topic of the research (Braun, et al., 2021; Hennink, et al., 2020).

To find out the situation in STEM education in the context of learning skills, a systematic review and an empirical study – a students' survey – were performed. Thus, it is possible to evaluate to what extent students' opinion that results from their experience at school corresponds to the research-based views of experts.

The study consists of two parts: first, to clarify the learning skills, a systematic review of two internationally significant databases Web of Science (WoS) and SCOPUS) was performed and then first-year students of four different faculties of the University of Latvia were surveyed about their learning skills acquired at school. The study was performed from 2018 to 2021. The methodology and findings (Birzina et al., 2022) were refined in 2023.

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Instrument and Procedures

Systematic Review

The quantitative and qualitative exploration was performed in WoS and *SCOPUS* databases, based on the systematic approach (Booth et al., 2016). First, key words "*learning skills*" were selected for searching for the information, then "*STEM education*" and "*Science education*" to define the education domains. As the second part of the study concerned the exploring of first-year students' opinion about the learning skills at school then the selection was limited to key words "*school*" and "*students*".

The year when the article was published, the language of the article, and the place of publication – whether the article was published only in research journals and conference proceedings as well as in the chosen databases, excluding those articles that were accessible in both databases served as the restrictive criteria for the systematic review (Table 2).

Table 2
Inclusion and Exclusion criteria

Inclusion criteria	Exclusion criteria
Research published between 2010-2021	Any studies not published between 2010-2021
The article was written in the English language	The article was not written in the English language
Articles published in journals and conference proceedings	Articles not published in journals and conference proceedings
The target group is school students or first-year students	The target group is not school students or first-year students
The study performed in formal school education	The study not performed in formal school education
Available within the two databases Web of Science and Scopus	Any duplicated research articles

Students' Survey

Sample

The survey was performed from 2018 to 2021; the participants were 242 first-year students of the science faculties of the University of Latvia (male $N = 50$; female $N = 192$). Of them, 32 % represented the Faculty of Biology, 14% – Faculty of Chemistry, 21% – Faculty of Physics, Mathematics and Optometry, Faculty of Geography and Earth Sciences, 12% and 12% – Faculty of Medicine. Most of the students (56%) had attended secondary general comprehensive schools in different regions of Latvia, and 44% had graduated from schools in the capital of Latvia Riga.

Students' survey was carried out in the electronic *QuestionPro* environment, using open-ended, and closed-ended questions. The survey was anonymous, and the results were analysed in a summarized form.

The aim of the survey was to find out the views of the first-year students on their learning experience and its importance. It had three parts: a) information on student's learning at school, b) assessment of studies at the university and c) student's engagement in the study process. The research was based on students' answers to the open-ended question *Q11 Name three most important learning skills that you have acquired at school.*

The qualitative and quantitative analysis of the obtained data was performed by coding the data using the data processing program AQUAD.

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Table 3
Conceptual Coding System Used for Data Processing

Cognitive skills	Interpersonal skills	Intrapersonal skills
Cogn_Numeracy	Inter_Collaboration	Intra_Adaptation
Cogn_Creativity	Inter_Communication	Intra_Grit
Cogn_Information	Inter_Leadership	Intra_Metacognition
Cogn_Inquiry	Inter_Presentation	Intra_Motivation
Cogn_PriorKnowledge	Inter_Teamwork	Intra_Responsibility
Cogn_ProblemSolving	Inter_Diversity	Intra_SelfDevelopment
Cogn_Reading		Intra_SelfManagement
Cogn_Remember		Intra_SelfDirection
Cogn_Technology		Intra_SelfRespect
Cogn_Thinking		Intra_TimeManagement
Cogn_Writing		

Data Analysis

In order to do data processing, a coding system was developed with students' *Speaker codes* (/$Student1…/$Student242) and *Conceptual codes* (Table 3) which described the learning skills cognitively, interpersonally and intrapersonally (Cimatti, 2016; English, 2017; Fan & Ritz, 2014; Geisinger, 2016; Putra et al., 2020; Siekmann & Korbel, 2016; Soland et al., 2013). The qualitative research followed the typical phases of qualitative analysis: the reduction of the original data, the reconstruction of linkages, and the comparison of findings (Huber & Gürtler, 2013). The category systems were adapted from the publications of the above-mentioned authors; the interpretation of the text was focused on whether the categories were used consistently and whether they corresponded to the content of the text passages. After coding the text, the qualitative data was transferred into a quantitative format, determining the frequency of codes as well as the relation between statements of learners, linkages among the codes were constructed.

Research Results

Findings of the Systematic Review

Initially, 4899 records/entries were found in both databases. During the selection their number was decreased, using the restrictive key words. In the end, 23 corresponding articles were found in both databases, of which 14 articles were excluded, as they did not comply with the defined criteria (Table 2). Thus, nine articles were used for a profound study (Figure 1).

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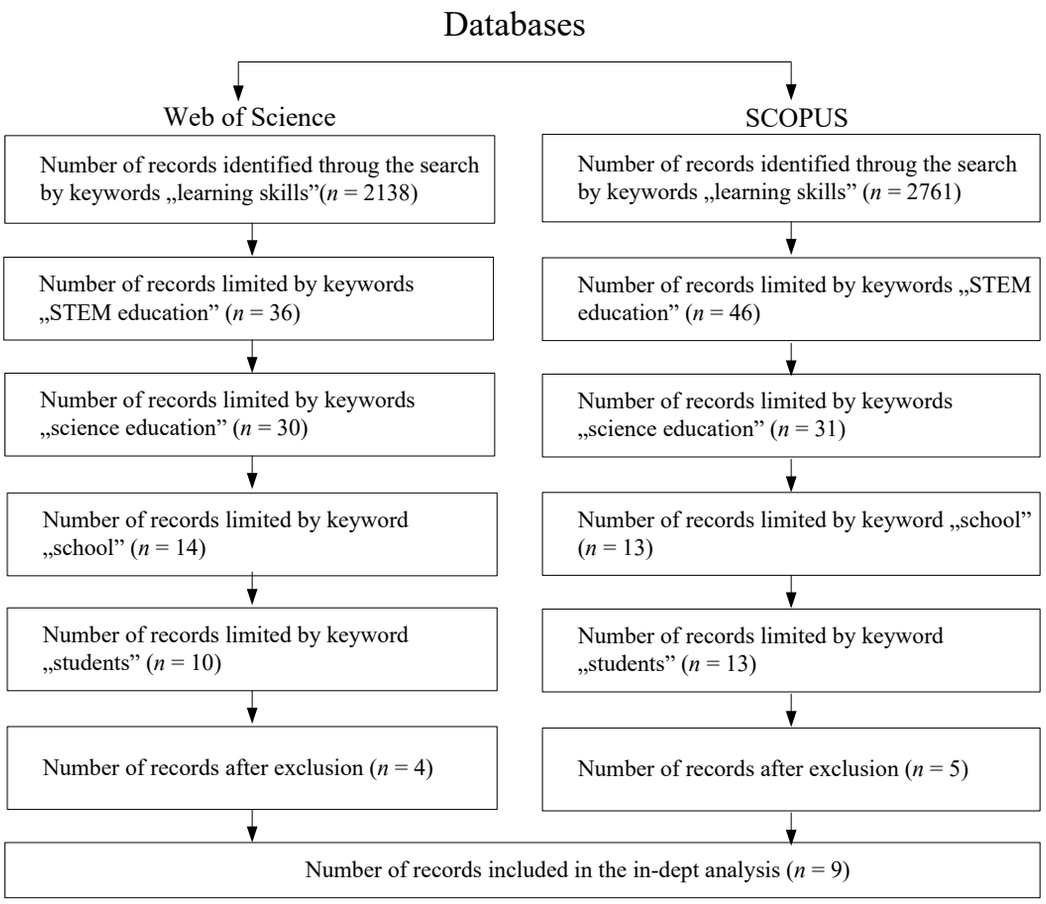
Figure 1
Results of the Systematic Review



The analysis of articles was performed identifying learning skills for STEM and science education. The obtained findings are summarised in Table 4.

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Table 4
Learning Skills that are Necessary for Acquiring STEM Subjects

Author, year	Cognitive skills	Interpersonal skills	Intrapersonal skills
Boonchom, 2021	Problem solving, creativity	Communication	
Vega, et al., 2019	Critical thinking, creativity, inquiry	Communication, collaboration	
Corneal, 2019	Note taking, preparing for classes and exams, reading STEM textbooks		Time management, avoiding procrastination
Bonora, Martelli, & Marchi, 2019	Prior knowledge, creativity. Smart Cities technology: the video-game, high-order thinking, digital knowledge	DIGITgame - a new approach to communicate	
Knowles, Kelley, Sung, & Choi, 2017	Engineering technology skills, scientific inquiry, information literacy, project-based learning skills		Self-efficacy
Saleh, Muhammad, & Abdullah, 2020	STEM project-based approach, science concepts, conceptual understanding, high-order thinking, creativity		Adaptation to complexity, management, self-regulation, curiosity, risk-readiness
Saad, &Verner, 2019	Acquiring concepts, experimental activities in a robotic environment, solving practical problems		Attitudes towards studies of physics
Ismail, et al., 2017	Knowledge, green practices skills, intellectual skills	Communication	Environmental awareness, self-management, entrepreneurship
Nawi, et al., 2019	Cooperative problem-based learning, knowledge, information seeking	Collaboration	Self-directed learning

It is evident that the majority of selected articles were published in conference proceedings during the period from 2017 to 2021. This means that authors have participated in conferences devoted to concrete STEM subjects and thus mainly the cognitive skills are emphasised: preliminary subject knowledge necessary for acquiring the science concepts and for conceptual understanding, scientific inquiry, engineering technology design and experimentation, as well as a problem-based and project-based approach that develop learner's creativity and high-order thinking skills. Mutual collaboration and communication are stressed regarding the interpersonal skills, innovative digital communication has also been pinpointed (Bonora et al., 2019). Time-management, self-efficacy and self-regulation that ensure self-directed learning are mentioned as intrapersonal skills, emphasising learners' attitudes and values (e.g., development of environmental awareness) when acquiring STEM that could be useful in promoting entrepreneurship and choosing the profession.

Findings of the Students' Views about Learning Skills

Responses given by students were coded with the help of the AQUAD program in accordance with the developed coding system; after that the frequency of the used codes was calculated (Table 5) and mutual linkages were constructed.

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Analysis of the Code Frequency

In order to find out students' views on the learning skills mastered at school, their answers were coded, and the frequency of the used codes was determined.

Table 5
Frequency of Codes in the Students' Survey

Cognitive skills		Interpersonal skills		Intrapersonal skills	
Code Cogn_	**Frequency**	**Code Inter_**	**Frequency**	**Code Intr_**	**Frequency**
Thinking	41	Communication	63	SelfManagement	97
Information	32	Collaboration	35	TimeManagement	63
Reading	20	Teamwork	33	SelfDevelopment	51
Writing	20	Diversity	24	SelfDirection	47
PriorKnowledge	20	Presentation	24	Grit	40
Numeracy	8	Leadership	2	Responsibility	38
Inquiry	7			Metacognition	36
Problem solving	4			SelfRespect	29
Remember	3			Motivation	21
Technology	3			Adaptation	20
Creativity	2				
Total	160	Total	191	Total	456

Note. Adapted Soland et al., 2013; Fan, & Ritz, 2014; Siekmann & Korbel, 2016; Cimatti, 2016; Geisinger, 2016; English, 2017; Putra et al., 2020

Students consider that the chief learning skills acquired at school are intrapersonal skills (n = 456), of which the most important are self-management, time-management, and self-development. This means that students have internal motivation for persevering self-directed learning process, they can learn themselves and are able to adjust and take responsibility for their learning. It has always been important for them during the school learning process to develop their interpersonal learning skills (n = 191), especially they have emphasised communication, collaboration and teamwork skills as well as public presentation skills. The first-year students, to a certain extent, can also adjust their individual needs to their groupmates and accept the groupmates' diversity.

> A quote from students' responses.
> /$Student10. *My adjustment to people* [code: Intra_Adaption] *with a different character and learning specifics* [code: Inter_Diversity]. *Work in the team* [code: Inter_TeamWork]. *The ability to choose what is really important to be learnt and postpone what is not so important* [code: Intra_SelfManagement].

Cognitive skills have been mentioned numerically a bit less (n = 160). These skills are mainly connected with the formation of higher-order thinking applying searching for and selecting the information.

> A quote from students' responses.
> /$Student130. *The skill of planning my time* [code: Intra_TimeManagement], *searching for information* [code: Cogn_Inform] *and analysing it* [code: Cogn_Thinking]

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Preliminary knowledge is important in the learning process. It is interesting that students in their answers indicate not only STEM subject knowledge but also the knowledge of foreign languages (mainly English and German, but also Norwegian and Danish have been mentioned). It should also be pointed out that for successful studying at the university, as students admit, general skills – reading, writing and numeracy literacy are important.

> A quote from students' responses.
> /$Student226. *Mitochondrion is the "power station" of the cell* [code: Cogn_PriorKnowledge, code: Cogn_Remember]. *Magnesium burns with a white flame* [code: Cogn_PriorKnowledge, code: Cogn_Remember].

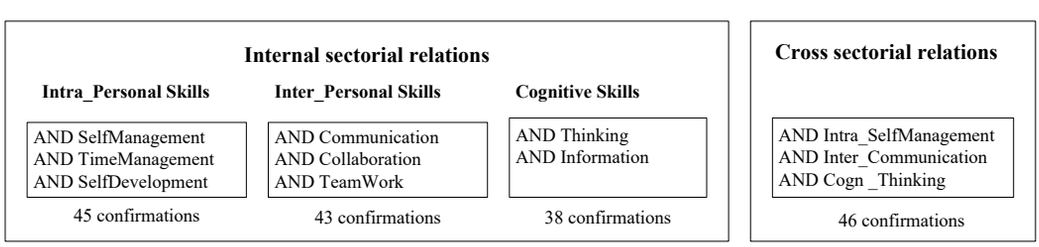
Differing from the systematic review data, students' responses do not show project-based learning skills, also problem-solving skills are little mentioned (n = 4). The number of inquiry skills is also small (n = 7), yet the answer has been substantiated.

> A quote from students' responses.
> /$Student225. *At present it is difficult for me to decide which are the skills acquired at school or during the first study year immediately after graduating the secondary school, but I think that one of the chief skills I gained at school was the basis of inquiry* [code: Cogn_Inquiry]. *Preparing my scientific research work I got an insight into the process of writing such works, gained insight into research methodology* [code: Cogn_Inquiry], *and learnt the skill of formal writing* [code: Cogn_Writing]. *During my school years, I also gained a rather broad insight into different science fields* [code:Cogn_PriorKnowledge], *for example, in chemistry laboratory making different experiments* [code: Cogn_Inquiry], *as well as I got to know the language as a tool for expressing my thoughts* [code:Inter_Presentation], *being able to use it effectively* [Intra_Respect], *both as literature* [code:Cogn_Reading] *and creative personal expression* [code: Cogn_Creativity], [code: Intra_SelfDevelopment].

Constructed Linkages

Because the AQUAD program reports the findings by showing the positions within the linked segments (Huber & Gürtler, 2013), in order to identify the mutual relations among the most frequently mentioned learning skills (Table 5), linkages were constructed. Internal sectorial and cross-sectorial relations (Figure 2) were established, which serve as evidence for the homogeneity of students' opinions because the most important learning skills match. This means that the learning experience gained in different schools of Latvia is similar and useful for the acquisition of STEM at the university.

Figure 2
Constructed Linkages



Note within a distance of maximally 3 lines of text

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Discussion

The results of the systematic review on learning skills that are necessary for acquiring STEM subjects (Table 4) highlight mainly cognitive skills. These skills are necessary for building scientific understanding in STEM subjects, underpinning the role of subject knowledge, as well as noting active engagement in scientific research and experimentation, real-life problem solving and project-based approaches, thus developing students' creativity and higher order thinking skills. Such emphasis on STEM cognitive learning skills has been also found in authors' previous studies (Birzina et al., 2021; Cedere et al., 2020). Such researchers as Beers (2011), Siekmann and Korbel (2016), and Calalb (2021) also stated that learning by doing, active learning, learning by understanding, inquiry-based science education, problem- and project-based learning describe the learner's engagement in science learning. Project-based learning can involve research and experimentation and increases content knowledge and motivation to learn (Spires et al., 2022).

The systematic review also highlights the importance of interpersonal skills, mentioning cooperation and communication, as well as innovative digital communication. This shows that STEM education focuses not only on the acquisition of knowledge but also on the social skills needed for today's labour market. Among intrapersonal skills, time management, self-efficacy and self-regulation as enabling self-directed learning are highlighted. They are important in terms of students' attitudes and values, which can be useful for entrepreneurship and career choice. Soft skills thus complement disciplinary knowledge and are needed in all professions. These skills include personal capabilities that enhance performance (Aznam, 2020), facilitate personal and professional interaction, teamwork and leadership skills, work ethics, intercultural knowledge and digital skills, and not only reflect personal capabilities but also include social responsibility, creativity, ethics and emotional intelligence (Villán-Vallejo et al., 2022).

Overall, these findings characterise the didactics of STEM education at three levels: (1) the theoretical level, including the research area of the STEM subject, (2) the practical level, exploring teaching and learning, and (3) the discursive level, discussing issues of teaching and learning (Birzina, 2023).

The results of the student survey are shown in Table 5. Intrapersonal skills and interpersonal skills are the most emphasised, demonstrating an understanding of the importance of personal development. Students consider intrapersonal skills, especially self-management, time-management, and self-development to be the most important skills they learn at school. They are essential for a self-directed learning process in which the ability to adapt, take responsibility and successfully learn independently at school. Equally important are communication, cooperation, and teamwork skills. Students believe that they can be tolerant towards their classmates: adapt their individual needs to the needs of their group members and accept the diversity of their group members. Thus, students develop these skills already during the school years and they can be useful in the future, especially in work situations that require cooperation.

The obtained findings, to a certain extent, confirm the conclusion of the authors' previous studies (Birzina & Cedere, 2017; Birzina et al., 2019) that interpersonal and intrapersonal skills, in particular, are important for first-year students and they give them significance already learning at school. This understanding is closely linked to the increasing recognition and demand for "soft skills" as a criterion for determining employability in the labour market in recent years. Skills such as leadership, creativity, communication, management, professionalism, ethics, agility, flexibility, and resilience are the standard professional requirements of the 21st century (Villán-Vallejo et al., 2022). The work of Greek researchers Mitsea et al. (2021) presents similar findings; it recognises that the metacognitive approach can be used in different educational contexts as a learning paradigm to accelerate students' integration into the learning process and

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enhance their performance. Other researchers (Malykhin et al., 2021) are convinced that 'soft skills' are transversal in nature and consider them as personal and interpersonal meta-traits and meta-abilities that are vital for anyone. Self-regulation (self-management, self-direction, and time-management) can be seen as a particularly important skill. It is a crucial factor not only in the context of the COVID-19 time-based online learning environment, demonstrating the ability to adapt and choose flexible learning strategies (Chitra et al., 2022), but also throughout the face-to-face study process to be able to achieve one's goals and succeed in a career (Sambell et al., 2021). In fact, soft skills are important in different areas of life, but it must be acknowledged that their role in learning performance has not been studied systematically (Feraco et al., 2022).

Cognitive skills (Table 5), in particular, the development of higher order thinking related to information search and selection, are important in the learning process. Students at the University of Latvia point to both the prior knowledge of STEM subjects and research activities, as well as foreign language skills, which are necessary in today's globalised world. It should be noted that general skills such as literacy and numeracy are considered important. Thus, these basic skills are seen as integral to preparation for university.

Osborne (2013), some time ago, argued that 21st-century education must increasingly focus on higher-order thinking, namely, synthesis, analysis and evaluation, but lower-level cognitive demands with an emphasis on lower-level recall still dominate school science education. Cognitive skills are precisely those skills that help construct knowledge, make assumptions, develop competence and the ability to solve problems and formulate results (Hasanah & Shimizu, 2020). In fact, STEM curricula define the knowledge and skills to be acquired in a subject, indicating what is worth learning and what kind of thinking is valued (Johnson et al., 2022). In essence, STEM curricula should focus on (a) STEM-specific knowledge and skills, fostering the development of higher-level thinking; (b) competencies specifically, but not exclusively, related to STEM (e.g., critical and creative thinking); and (c) generic competences (e.g., collaborative or communicative skills) that can be productively developed in a STEM context (Siekmann & Korbel, 2016). According to the OECD (2020) data, of the transformative competencies, creating new value (35%) is more common in STEM curricula than taking responsibility (29%). On average across countries, cognitive competencies are the most emphasised: critical thinking (66%), followed by problem solving (59%), then learning to learn (36%). Socio-emotional skills and attitudes such as cooperation and respect (more than 30%) are also included in the curricula. In the OECD (2021) PISA study, 54% of learners reported that they were taught to recognise whether information is objective or not at school. One can assume that information literacy is developed more in secondary school.

It is worth noting the differences between students' responses and the systematic review data. Students' responses have less emphasis on project-based learning, problem-solving skills, and research skills. These differences may indicate that students' perceptions of the skills they have acquired may be subjective or that they may not be fully aware of what they have learnt. At the same time, quotations from students' responses are a good illustration of students' experience and self-awareness. In conclusion, the authors' study shows that the school years are an important phase in which students acquire cognitive, interpersonal, and intrapersonal skills.

Research on students' learning skills can be crucial for understanding the educational process and students' performance, but it often simplifies the complex cognitive and emotional activities that take place in practice. One of the main limitations of this study is that it analyses students' responses to only one open-ended question, which may not provide enough diversity of information in the context of university study, as students' understanding may be incomplete, and it may be difficult to include all skills and their development in a single question. At the same time, previous studies by the authors (Birzina & Cedere, 2017; Birzina et al., 2019) provide similar results for this target group. As a limitation, one can also mention the coding process in qualitative data processing, where the subjective moment of interpretation cannot

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be excluded. To address these limitations, research methods should be expanded, and attention should be paid to research design, data acquisition and analysis. It is therefore essential to use different approaches and to take into account the context in which the development of learning skills takes place.

Conclusions and Implications

In order to prepare for 21st-century science studies, students need to gain sufficient basic knowledge in the subject, acquire skills that are necessary to engage in scientific inquiry, and to develop complex epistemic views to comprehend the essence of science. To achieve this, they need cognitive general and STEM discipline specific learning skills as well as interpersonal and intrapersonal skills.

There are no principal differences in the evaluation of hard and soft skills in the systematic review and students' responses. Latvian students, too, have developed the most characteristic 21st-century skills at school. Students mention such interpersonal learning skills as communication and collaboration as the most important soft skills, and from intrapersonal skills – self-management, time management and self-development, that ensure self-directed learning and form the learner's attitude. The information selected in the systematic review is more connected with the science education conferences, thus it mainly stresses the preliminary subject knowledge, scientific inquiry, engineering technology skills and experimentation as well as problem-based and project-based approach that develop the learner's creativity and higher-order thinking skills. Latvian students also emphasise such cognitive general learning skills as high order thinking and information literacy, reading, writing and numeracy literacy. Differing from the data of the systematic review, students in their responses have less mentioned such important skills for STEM as inquiry and problem-based learning skills.

In general, the obtained findings show a good correspondence of learning skills important for the STEM domain that the University of Latvia students have acquired at school to the researchers' latest conclusions, which, in turn, serve as evidence of the appropriateness of these learning skills to science studies at the university. It also helps to understand how students evaluate their skills and the role of different skills in the learning process. It can provide a basis for future research on the relevance of educational reforms and the development of teaching methods to equip students with the skills they need in the future.

Note

The results of the study are presented in 2023 in the V International Baltic Symposium on Science and Technology Education „Science and technology education: new developments and innovations", BalticSTE 2023 (Šiauliai, Lithuania).

Declaration of Interest

The authors declare no competing interest.

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