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The Possibilities of Developing STEM Skills in Higher Education

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The development of information and technology in recent decades has entailed a change of attitudes in higher education. In addition to academic knowledge, it is becoming increasingly important for students to acquire up-to-date, practical knowledge that will help them find their place in the world of work and in everyday life. Based on international analyses, the following characteristics, so-called soft skills, are essential on the labour market: higher-level thinking, communication skills, cooperation, self-control and a positive self-image. In our paper, we examine the possibilities of skills development in the field of STEM, especially in engineering education. In our university's engineering teacher training, we strive to develop our students' STEM skills using a variety of methods, and prepare them for the teacherly task of being able to effectively develop their own students' skills and motivate them in STEM areas. This requires students to view their own learning process not as passive onlookers but as active participants. In our paper, we present some methods that can be effectively applied in STEM areas (e.g. discussion, collaborative learning, cooperative methods, project method, problem-based learning, inquiry-based learning, gamification, the use of robots in education).

Keywords: *STEM, skills development, educational methods, teacher training*

Introduction

STEM includes the areas of **S**cience, **T**echnology, **E**ngineering and **M**athematics. Its essential feature is the use of scientific, technical and mathematical knowledge to solve everyday tasks or social problems. It is characterised by a complex and interdisciplinary approach.

"STEM competency refers to an individual's ability to apply STEM knowledge, skills and attitude appropriately in his or her everyday life, workplace or educational context" (Boon 2019, p. 11).

STEM competency includes the "know-what", i.e., the knowledge, attitudes and values attached to the areas of science, as well as the "know-how", i.e., the skills necessary for the application of this knowledge (Boon 2019). It is important not to treat these components in isolation but rather in a holistic way.

The aim of teaching STEM areas is not only to develop cognitive skills, but also to develop soft skills such as problem solving, collaboration and communication skills. This is extremely important because nowadays, as a result of the 4th industrial revolution, the range of expected skills and abilities on the

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labour market has changed, and the demand for the development of soft skills has come to the fore (Kersánszky and Nádai 2020). STEM teaching is key in the preparation of students for the world of work (Kefalis and Drigas 2019). Improving STEM skills is possible through varied teaching methods.

The Skills Necessary on the Labour Market

The development of information and technology in recent decades has entailed a change of attitudes in higher education (Wolhuter 2020). In addition to academic knowledge, it is becoming increasingly important for students to acquire up-to-date, practical knowledge that will help them find their place in the world of work and in everyday life. This also necessitates knowing the demands of the labour market (Alter and Kocsis 2021, Szabó and Barta 2020).

Several studies explore what characteristics are expected by employers besides professional knowledge.

On the basis of national and international analyses, Daruka (2017, p. 10) lists the five most important soft skills which can be considered critical from the aspect of labour market preferences:

- Higher-level thinking (critical thinking, problem solving, decision making).
- Communication skills (oral and written, in one's mother tongue and in foreign languages).
- Cooperation (e.g., context-dependent behaviour, conflict management).
- Self-control.
- Positive self-image (self-confidence, self-knowledge, self-effectiveness, self-worth).

Between 1997 and 2002, a large-scale competency survey was conducted in 12 OECD countries, during which researchers compiled a competency list. Organised into three groups, the list contains a total of 23 competencies that, based on research in the Member States, are specific to the employee who can ensure the future competitiveness of the organisation (cited by Karcsics 2007, p. 62).

Key competencies:

- Communication.
- Quantification skills.
- Teamwork.
- Problem solving skills.
- Learning and performance development.

Work competencies:

- Flexibility.
- Creativity.
- Initial independent decision.
- Ability to act.
- Foreign language skills.
- Self-confidence.
- Critical approach.
- Exploring possibilities.
- Responsibility.

Leadership competencies:

- Leading.
- Motivating other people.
- Learning from mistakes.
- Building and maintaining relationships.
- Influencing other people.
- Decision making.
- Focusing on results and completing processes.
- Setting up a strategy.
- Ethical attitude.

A particularly important question in engineering education is what abilities and skills are essential for an engineer in a rapidly changing information society (Conlon 2008, Lappalainen 2009, Williamson et al. 2013).

Already during their studies, engineering students face a variety of challenges to successfully complete their education. For example, critical thinking and technical skills are considered essential (Noonan 2017, Szabó and Bartal 2020).

There is a growing demand on the labour market for flexible, adaptable and communicative engineers (Kolmos 2006). Employers expect fresh graduate engineers to have not only professional knowledge but also qualities such as problem solving, openness and creativity so that they can deal with people as well as work in a team.

Engineers need to collaborate with other engineers, their subordinates, marketing and financial experts, merchants, and many other corporate employees, as well as representatives of other companies, foreign partners, and even communicate with users (e.g., when presenting products) (Bajzát 2010). Soft skills provide the basis for the effective handling and management of problem situations (Schulz 2008).

Engineering education focuses primarily on the development of professional competencies and technical skills, but it would also be important to prepare students for the demands of the workplace. Schomburg (2007) draws attention primarily to the lack of social, communicative and personal competencies. Other

studies have highlighted the importance of interpersonal skills in engineering (Direito et al. 2012, Berglund and Heintz 2014), and emphasise the need to rethink "traditional pathways" in engineering education as a result of technical changes, and to develop competencies which meet the expectations of the labour market.

Literature sources also point out that personality traits play an important role in terms of working ability and job satisfaction, and are therefore regarded as key characteristics of the engineering profession. According to the research results of Williamson et al. (2013), the studied engineers differ from the research subjects of other occupations in that they have more intrinsic motivation and are more persistent, but less characterised by the following qualities: self-confidence, conscientiousness, extroversion, emotional stability and optimism.

Other studies (Lappalainen 2009, Direito et al. 2012) have also drawn attention to the weaknesses of engineers: effective communication, cooperation, teamwork, project management and lifelong learning tend to pose difficulties for them.

According to the reports issued by the World Trade Form, the skills preferred by the labour market are continually changing. The priority has shifted towards soft skills. Based on the ranking of the 2020 report, the most important skills on the labour market in 2025 will be the following (World Economic Forum 2020):

1. Analytical thinking and innovation.
2. Active learning and learning strategies.
3. Complex problem-solving.
4. Critical thinking and analysis.
5. Creativity, originality and initiative.
6. Leadership and social influence
7. Technology use, monitoring and control.
8. Technology design and programming.
9. Resilience, stress tolerance and flexibility.
10. Reasoning, problem-solving and ideation.
11. Emotional intelligence.
12. Troubleshooting and user experience.
13. Service orientation.
14. Systems analysis and evaluation.
15. Persuasion and negotiation.

Analytical thinking, innovation, active learning and complex problem solving are essential in the future labour market. Therefore, an emphasis should be placed on the development of these skills in higher education.

In Hungary, several studies have examined how the demands and expectations of employers appear in job advertisements.

In his study published in 2006, Híves analysed what aspects the labour market considered most important on the basis of 954 job advertisements targeting graduate employees.

The results of his research showed that foreign language skills, informatics and professional experience are outstanding among the expectations. Firstly,

employers expect a number of professional competencies that can be acquired through study or employment. Secondly, they also require general competencies related to work activities, which in many cases are related to the personality traits of employees. Thirdly, they expect qualities that are related to fellow employees, the company and working conditions. The results of the research call attention to the fact that a good demeanour and good communication skills are essential. In addition, problem-solving skills, organisational skills and leadership skills are emphasised. The expectation of independent work is of paramount importance.

Bajzát (2011) analysed in her research 1000 job advertisements for mechanical engineers. She found that all advertisements contained foreign language skills requirements. 60.5 per cent of job advertisements also included expectations of other competencies. Based on the results, it can be stated that companies are primarily looking for engineers who have good communication, problem-solving and teamwork skills.

Selmeczy (2006) assessed the needs of the labour market divided into different job areas. In his research, he came to the conclusion that the most important skills in the evaluation of graduates are:

- Accurate work.
- ICT knowledge.
- High workload capacity.
- Foreign language skills.
- Teamwork.

Besides the above, the following are also important:

- Working independently.
- Foundational professional knowledge.
- Professional experience.
- Organisation skills.

In Selmeczy's research, what repeatedly surfaced in interviews with experts was that engineers did not have a good enough demeanour or enough knowledge about practical applications and the operation of companies and also that their foreign language skills were often inadequate. On the other hand, they had a strong idea that what they wanted to do, they were calm and would persevere in a company and an occupation.

Some of the responding employers emphasised the lack of work experience and foreign (mainly professional) language knowledge in the case of graduate career starters. The first expectation raises the important question of how career starters can be expected to have (several years of!) work experience.

The dual training introduced at our university seeks the resolution of this antagonistic contrast in the scheme that, in addition to their university student status, students also gain work experience with partner companies in parallel with their higher education.

In a study by Kiss (2010), he compared the opinions of new graduates and employers about the competencies needed by career starters. Based on the data obtained, a striking difference can be observed: recent graduates rated precise and independent work, high working capacity and interpersonal and communication skills as the most important, while employers rated entrepreneurship, foreign language skills, analytical approach and professional theoretical foundations as key.

The study of Ablonczyné and Tompos (2007) also showed that companies value in career starters high-level foreign language communication competencies, reliable work, creativity, teamwork skills, flexibility, problem-solving skills and initiative.

In her research based on the analysis of the Hungarian press, Czenky states that what employers value is "the so-called marketable knowledge, expertise and professional knowledge, which can be used directly in practice, rather than purely theoretical knowledge" (Czenky 2006, p. 124).

According to a survey of the Northern Great Plain region, corporate experts drew attention to the importance of the following competencies: responsibility at work, independent work and problem-solving skills, followed by professional competence (Polónyi 2007).

Pénzes et al. (2012) assessed labour market expectations among organisations operating in Central and Eastern Hungary. According to the results of the research, the surveyed organisations considered good communication skills to be the most important requirement for career-starting graduates. Possession of a high level of theoretical knowledge and the ability to utilise it, as well as high-quality foreign language communication were also among the most important requirements. The companies surveyed also stated which areas they were most dissatisfied with when employing young career-starters. The standard of oral communication came first, followed by the lack of negotiation-level foreign language skills and that of professional experience. Another problem identified was the lack of a goal-oriented approach and strategic thinking, and a low level of motivation, willingness, self-knowledge and independence. In contrast, they were satisfied with the graduates' professional theoretical knowledge and its effective application in practice.

The current challenge for higher education institutions is to train students in a way that they would be able to stand their ground on a labour market with changing demands.

STEM Skills

A degree in STEM fields appears as a competitive advantage in the job market. According to Noonan (2017), students studying in STEM courses and employees performing jobs in STEM-related workplaces are of paramount importance to the economy and industry.

However, a number of problems arise in this area. For example, there are not enough applicants for some engineering courses, there is a high drop-out rate

during the programme, especially in the first and second semesters, and there is a large gap between the theory taught at university and the practice of corporate industrial production.

The main goal of STEM courses is not to educate intellectuals in the classical sense, but professionals with the specific knowledge and the greatest chance to satisfy the needs of the labour market (Alter and Kocsis 2021). In order for the student or employee to succeed in the STEM fields, in addition to theoretical knowledge and cognitive skills, emphasis must also be placed on the development of soft skills, which requires deliberate preparation.

The skills required to perform tasks in STEM areas include cognitive, manipulative, technological, as well as collaborative and communicative skills (Boon 2019).

Cognition refers to the mental process of understanding through thinking and experience. Cognitive skills include: information management and processing; identifying, collecting, processing and using relevant data to make decisions; critical, creative and analytical thinking; problem solving; scientific investigation; creativity and computational thinking.

Manipulation and technological skills refer to psychomotor skills, which are required for the correct and safe use and operation of scientific and/or technical equipment and the correct and safe handling of various substances.

Collaboration and communication skills can be developed and improved through effective teamwork. Effective collaboration is achieved when team members set common goals, are given equal opportunities to participate and communicate ideas, and everyone takes equal responsibility for their work.

Also important in STEM areas are the so-called transversal (cross-curricular, inter-curricular) competencies, which are general skills that are independent of school subjects and cannot be linked to a specific discipline, but can be widely applied. They enable adaptation to change and also contribute to motivation and job satisfaction that affect the quality of work (Säävälä 2011).

Transversal competencies (Lukácsné Ujhegy 2013) are the following:

- Learning to learn independently.
- Social competencies.
- Cooperative activity.
- Critical thinking and reflection.
- Digital competency.

In its report, the UNESCO separated the following transversal competency areas (Care and Luo 2016, p. 11, Sheffield and Koul 2021, p. 5).

- Critical and innovative thinking (creativity, entrepreneurship, resourcefulness, application of skills, reflective thinking, reasoned decision-making).
- Inter-personal skills (presentation and communication skills, leadership, organisational skills, collaboration, initiative, sociability, collegiality).

- Intra-personal skills (self-discipline, engagement, perseverance, self-motivation, compassion, integrity, commitment).
- Global citizenship (awareness, tolerance, openness, respect for diversity, intercultural understanding, ability to resolve conflicts, civic/political participation, conflict resolution, respect for the environment).

These competencies deserve special attention in the STEM areas.

Some characteristics of the development of transversal competencies (Lukácsné Ujhegy 2013):

- They improve through teamwork.
- They require verbal and/or written communication in the mother tongue or in a foreign language.
- Their development and improvement are supported by the application of communication techniques and computer technology.
- Their development and improvement also require and assumes decision-making and problem-solving strategies and techniques.
- During their development and improvement, individual and social characteristics and differences are respected and the opportunities provided by multiculturalism are valued.
- Its objectives include autonomous learning, entrepreneurship, initiative and openness to innovation.
- Professional ethics and values are respected.

Research into Soft Skills Necessary in the STEM Areas

In the following, we outline the results of two of our own studies. Both are related to engineering education. The first was conducted among engineering students and the second among employers. Both studies aim to assess the soft skills needed on the labour market. Our research question was which soft skills were considered to be the most important in the labour market by students and which by employers.

Our attention was drawn to the need for skills development by our empirical study of 475 first-year engineering informatics students, in which we examined on one hand, how important students considered a given competency to be for their future profession and on the other hand, to what extent they currently had that competency.

Respondents evaluated 24 characteristics on a 5-point scale. We examined the reliability of both competency lists: their Cronbach's alpha values were: 0.8160 and 0.8720, respectively, which we regarded as good results.

Table 1. *Means, Standard Deviations (SD) and Differences between the Perceived Importance and Self-Reported Proficiency Level of Competencies (N=475)*

	Importance (Mean)	**Own level (Mean)**	**Difference**	**Wilcoxon (Z)**
Oral communication	3.80	3.31	0.49	-8.525*
Problem solving	4.90	3.81	1.09	-17.678*
Ability to work precisely	4.76	3.75	1.01	-16.325*
Cooperation	4.22	3.90	0.32	-6.912*
Teamwork ability	4.25	3.88	0.37	-7.488*
Working independently	4.53	3.91	0.62	-12.402*
Analytical thinking	4.69	3.80	0.89	-15.110*
Learning ability	4.66	3.60	1.06	-16.008*
Innovation	4.64	3.68	0.96	-16.154*
Conflict resolution	3.23	3.53	-0.3	-4.694*
Organisation	3.53	3.28	0.25	-4.878*
Persistence	4.18	3.67	0.51	-8.686*
Written communication	2.97	3.33	-0.36	-6.179*
Openness	3.86	3.81	0.05	-1.275**
Goal orientation	4.57	3.91	0.66	-12.834*
Self-knowledge	3.20	3.65	-0.45	-6.994*
Stress tolerance	4.22	3.53	0.69	-10.324*
Responsibility	4.31	3.93	0.38	-8.036*
Adaptation to change	4.37	3.93	0.44	-8.887*
Concentration	4.74	3.65	1.09	-16.510*
Understanding causal relationships	4.80	3.95	0.85	-16.208*
Appling knowledge	4.77	3.97	0.8	-15.397*
Flexibility	4.29	3.82	0.47	-9.428*
Evaluation and self-evaluation	3.54	3.55	-0.01	-0.420**

*p=0.000

** Not significant

In students' opinion, the skill of problem solving is the most needed for their future profession (4.9 mean value on a 5-point scale). This is in keeping with the results of international studies which highlight the fact that the skill of problem solving is indeed one of the most important skills on the labour market (Daruka 2017, Karcsics 2007, Híves 2006, Bajzát 2011). In second place was the understanding of causal relationships (context) (4.8) and in third, the ability to apply the acquired knowledge (4.77). The students believed that the least necessary skills on the labour market were writing (2.97), self-knowledge (3.2) and conflict resolution (3.23) (Table 1).

Examining the relationship with the background variables, we found that while 90.7% of women consider the ability to learn to be very necessary in the labour market, this ratio for men is only 69.2% (based on the Chi-squared test performed on the data: p=0.029). The ability to understand context is also considered more important by women: according to 97.7% of them it is very necessary in the labour market, while 81.5% of men were of this opinion (p=0.042).

In their own opinion, respondents had the most skills in applying knowledge (3.97) and in understanding context (3.95). Responsibility and adaptability occupied the 3rd and 4th places, both with a mean value of 3.93. Based on the results, we found that students perceived shortcomings in all areas, as none of the average scores given to the assessed characteristics reached a value of 4 on the five-point scale. The results highlighted the importance of skills development.

Students often drop out because they are not able to adapt to the challenges of higher education, to process the material, to apply theoretical knowledge during their practice, they cannot understand context, cannot concentrate, are not accurate enough and are not persistent. The first-year students interviewed in the research consider themselves to have serious deficiencies in these areas. Solving this problem is a serious challenge for higher education institutions. Student mentoring programmes can be highlighted as good practice, the purpose of which is to provide assistance to students in navigating the world of higher education: studying as well as socialization.

Examining the relationship with the background variables, we found significant correlations in the following area: according to their own assessment, women possess stronger writing skills (41.9% to a great extent, 18.6% to a very great extent; while men have this skill 28.2 % to a great extent and 13.8% to a very great extent; Chi-squared test: $p=0.034$). Regarding responsibility, women are also better in their own opinion: 48.8% of them consider themselves responsible to a great extent, 25.6% to a very great extent; while 40.3% of men consider themselves to have this characteristic to a great extent and 29.4% to a very great extent ($p=0.017$).

The biggest differences between students' current competencies and those needed on the labour market were found in the areas of concentration of attention, problem-solving skills and the ability to learn, so development is especially necessary in these areas.

It is interesting to point out that in four cases (realistic self-esteem, self-knowledge, writing skills and conflict resolution), the students believed that they possessed the given competence to a greater extent than necessary on the labour market.

Our second study examined the other side: it assessed the demands of employers. Our university's 27 corporate partners identified the soft skills that they expected engineering students/fresh graduates to possess. Responding to the open-ended questions in the questionnaire, they articulated their expectations in three major areas: key competencies, work-related competencies and management competencies.

In the area of key competencies, 25 companies responded, naming a total of 103 non-professional skills. Most of them identified communication skills (14 mentions), followed by teamwork (11 mentions), problem solving (5 mentions), reliability (3 mentions), and accuracy (3 mentions).

17 respondents listed work-related competencies, giving a total of 25 answers to this question. Most of them mentioned independent work (11 mentions), followed by problem solving (5 mentions), teamwork (3 mentions), and proactivity (3 mentions).

14 respondents identified management competencies, giving a total of 41 answers. Most of them mentioned decision-making (8 mentions), followed by project-related skills such as project management (4 mentions) and problem solving (3 mentions).

Our study drew attention to those soft skills that are indispensable on the labour market (Holik 2019, Holik and Sanda 2022). By mapping employers' relevant competence requirements, our research contributes to content development: to the creation and launching of the university's new training programs, as well as to the development of the range of educational skills and the identification of critical needs. The results can also be useful for other higher education institutions in the STEM areas.

Development Possibilities and Methodological Recommendations

Although the frontal, knowledge-based form of education is also prevalent in STEM areas, it actually works better in groups with more homogeneous abilities and cannot take into account the individual abilities and skills of learners. It is not interactive, so it is unsuitable for the development of certain skills.

In the field of STEM subjects, a particularly important question arises as to how to motivate students, as math, physics, chemistry and biology usually seem scary to students. However, in order to make STEM subjects attractive, "traditional" frontal teaching is no longer an appropriate strategy – education requires constant renewal. The development of STEM competencies requires the use of methods by which participants recognise and identify their abilities and characteristics and consciously shape them through experiential learning and interactions (Seetha 2013).

In our university's engineering teacher training programme, we strive to develop our students' STEM skills using a variety of methods, and prepare them for the teacherly task of being able to effectively develop their own students' skills and motivate them in the STEM areas. This requires students to view their own learning process not as passive onlookers but as active participants.

In our training programme, we emphasise the following areas.

Methodological Competencies

- Pedagogical methodological readiness.
- Planning of pedagogical processes and activities and self-reflections related to their implementation.
- Planning, organising and evaluating the problem-solving teamwork.
- Usage of simulation software in order to reinforce theoretical knowledge (laws and connections).
- Summary and presentation of the results of the problem-solving groups in front of the plenum while applying an interactive whiteboard and video recording.

Competencies Related to the Renewal of Pedagogical Work

- Planning and organising learning process (experience-based learning, supported digital teaching methods).
- Modern methods of pedagogical evaluation.
- Well-motivated and effective teaching-methodologies.
- Gamification methods, their use in the teaching of STEM subjects.
- Designing an e-learning process, developing learning organisation and support skills.
- Content development of e-learning materials for self-study.
- Self-monitoring, control and evaluation, learning support solutions.
- Supporting the processing of STEM teaching materials with digital teaching tools (software, videos).

Additional Skills and Competencies

- Cognitive skills, information management and processing (identifying, collecting, processing and using relevant data to make decisions).
- Critical, creative and analytical thinking.
- Problem solving skills.
- Scientific investigation.
- Creativity and computational thinking.
- Manipulative and technological skills.
- Collaboration and communication skills (teamwork).
- Self-knowledge.
- Evaluation.
- Systems analysis.
- Creativity.
- Independent learning.
- Environmentally conscious (Novák 2020).

Attitude Characteristics

- Openness.
- Creativity.
- Self-expression.

In the following, we present some methods which can effectively be applied in STEM areas.

Teamwork, and discussion within a group, provides an excellent opportunity for students to express their thoughts, elaborate their own views, to argue and pay attention to the other party. **Dispute**, a game from the English language area that develops players' debating culture, can be very effective in developing discussion techniques (Hunya 1998). It aims to teach students the techniques that are essential for becoming a successful, critical, active citizen in an open, democratic society. It

enriches one's culture as well as entertains. The primary goal of the dispute is learning, which takes precedence over victory. Disputes can be made, for example, about a healthy lifestyle or the characteristics of different energy sources, the effects of littering, the environmental problems of using plastics, or even about the technical, legal and ethical aspects of obtaining and using information. In addition to reasoning, this method teaches attention to others, self-discipline, tactfulness and logical thinking.

Collaborative learning is an active and interactive process, an excellent opportunity to develop soft skills, as it aims to give students an active learning experience. In collaborative learning, the result of co-learning is the successful achievement of a common goal. Students achieve this through a joint activity that also indirectly develops their collaborative skills.

The use of **cooperative methods** also serves the development of soft skills because these methods are based on the cooperation of learners. The four basic principles of cooperative learning (Kagan 2015) are constructive interdependence, individual responsibility, equal participation and parallel interaction. In addition to increasing learning motivation and performance, this method promotes the building of positive relationships among students, strengthens cognitive development, and develops social and management skills (leadership skills, communication skills, conflict resolution, decision making, etc.) (Kagan 2015). Research results suggest that the use of cooperative learning techniques and courses to develop social skills have had a positive effect on cooperation at work and on personal relationships (Smith et al. 2005). In engineering teacher education, students are introduced to several cooperative methods and have an opportunity to try them out in small group sessions.

The application of the **project method** builds on the interest of students and the joint activities of teachers and students. Therefore, it is suitable for developing cooperation, empathy, conflict-management and communication skills. The focus of the project is generally a practical problem, so it provides an excellent opportunity to develop problem-solving skills. When applied, the traditional teacher-student relationship also changes. This is also important because proper cooperation between students and faculty is an essential condition for both academic and social integration. A study by Berglund and Heintz (2014) reports that project-based learning in a real workplace environment develops skills that facilitate students' employment, such as teamwork, communication, problem solving and conflict-management.

Problem Based Learning (PBL) can be particularly effective in STEM areas as it confronts students with practical problems, thereby preparing them for creative, critical and analytical thinking and for finding their own sources of learning. Students solve complex problems in group-work, using self- and peer assessment (Epstein 2004). The development of the ability to assess oneself improves the ability to assess one's peers, which in turn makes for an increasingly realistic self-evaluation, so the two abilities develop in parallel. Furthermore, students working in a group not only develop their problem-solving skills, but also their communication, cooperation and leadership skills.

In **Inquiry-Based Learning** (IBL), students conduct experiments, model and research, often in collaboration with each other. The method assumes the active involvement of students in the learning process, in the construction of knowledge. Inquiry-based learning contributes to students' understanding of the nature of science and the research methods of the natural sciences. They acquire general research skills (for example: formulating research questions, setting up hypotheses, planning and managing the research, analysing and publishing results) and specific research skills (for example: the use of microscopes, physiological and field research methods). Research activities can help to understand scientific content and apply scientific knowledge. Students can gain first-hand experience in research, scientific discoveries, which can help develop their interest in science, a willingness to research and positive subject attitudes (Nagy and Nagy 2016).

In **design-based learning** (DBL), also known as design-based education, students are involved in the design and even the development of scientific experiments. Students are not presented a ready-made curriculum, but have to design and then create an object, model, or other product themselves. Here, the processes of design and creation together create the opportunity for development (Schoenfeld 2006). This method allows students to explore and develop different technologies, consider limitations, security, and risks, and seek alternative solutions (Guzey at al. 2016).

Gamification refers to the application of games and game elements to non-game areas of life. The goal of gamification is to make educational processes more interesting and effective by helping students engage with the task, by activating both intrinsic and extrinsic stimuli. Initially, it arouses the curiosity of students and learning becomes an experience for them. Its motivating factor is rewards, which are the classic elements of gamification, such as completing levels, collecting reward points, competing and achieving rankings. Points are key indicators of performance, feedback tools, the quantified markers of win-states. Based on the main components of the reward system of computer games, we can talk about the Points, Badges, Leaderboards (PBL) models (Módné et al. 2022). Using gamification, participants are happy to complete the tasks. They are driven by the desire to overcome the challenges and solve the problems posed by the game. Furthermore, gamification can excellently be used in education to increase motivation as well as to develop skills (Duchon 2021, Frohmann and Damsa 2016). Nowadays, a number of online applications based on many aspects of gamification are available, which helps the work of the teacher. In our engineering teacher education programme, students try out a curriculum built on gamification aspects.

An innovative method is the use of **teaching robots** in education. Robots can be used as teaching assistants and pedagogical assistants in almost any field of science, but they can also play a role specifically in the teaching of computer programming (Nagy 2020). Educational robots help to master the basics of programming in a playful way, as well as developing logical thinking, spatial and temporal orientation, observation skills, attention, social skills, creativity and digital competence. The use of teaching robots can contribute to the development of students' problem-solving skills and algorithmic thinking. Educational robots

play a role in motivating students and arousing their interest. They provide space for experimental learning and contribute to the connection of STEM areas. During the training, our students become acquainted with the application possibilities of robots in the field of education. We plan to enable our students to gain their own experience in the future by using a teaching robot during classes.

The above methods contribute to making learning and teaching an experience. The roots of experiential pedagogy go back to the work of John Dewey, who believed that the student's own learning experience should be at the heart of any teaching-learning process. Methods that build on **experience-based learning** leverage the effective teaching power of direct experience and, through the processing of subjective experience, make experiences and learning permanent. When the new knowledge of the learning process can be linked to a relevant experience, it greatly helps to deepen and subsequently recall knowledge. Freund writes: "**It is** a very important, if not **the most important**, **task of teachers to stamp a positive emotional seal on the knowledge they want to share** (Freund 2014).

Mihály Csíkszentmihályi called it **flow experience** when we consider the majority of our work to be not really work because we find it interesting, it is a challenge for us, and the difficulties inspire us to find solutions. The solution and implementation fill us with joy and pride, making learning an enjoyable adventure. Flow "is the phenomenon when we are dissolved in an activity to such an extent that everything else dwarfs in comparison, and the experience itself becomes so enjoyable that we want to continue the activity at any cost, just for its own sake" (Csíkszentmihályi 2010, p. 22).

Summary

Nowadays, as a result of the 4th industrial revolution, the range of abilities and skills expected on the labour market has changed, and the need to develop soft skills has come to the fore. In higher education, in addition to the development of cognitive skills, the development of soft skills (such as problem solving, cooperation or communication) is becoming increasingly important. An essential feature of STEM areas is the use of scientific, technical and mathematical knowledge to solve daily or societal problems. STEM teaching is characterised by a complex approach and an interdisciplinary approach. STEM education is key in preparing students for the world of work. The development of STEM skills is possible through a variety of teaching methods, and this requires methodological renewal in higher education. Our paper presented the diversity of STEM skills and the possibilities for their development.

In Hungary, the lack of teachers in the STEM subject areas is a serious problem. The promotion of STEM subjects and the renewal of (subject-specific) methodology, on the basis of the above examples, will hopefully help to ensure the supply of teachers by increasing the number of candidates choosing these subjects when entering teacher education.

References

Alter E, Kocsis Zs (2021) Hallgatói munkavállalás a STEM területeken (Student employment in the STEM areas). *Új Munkaügyi Szemle* 4: 67–79.

Ablonczyné ML Tompos A (2007) Gazdasági szaknyelvi kommunikációs modell. (Business language communication model). In M Silye (ed.), *Porta Lingua – 2007. Szaknyelvoktatásunk – határokon átívelő híd*, 115–122. Debrecen: Debreceni Egyetem.

Bajzát T (2010) *A mérnökök kommunikatív és interkulturális kompetenciája: elvárások és felkészítés* (Communicative and intercultural competency of engineers: expectations and preparation). Pécs: Pécsi Tudományegyetem (University of Pécs).

Berglund A, Heintz F (2014) Integrating soft skills into engineering education for increased student throughput and more professional engineers. In *Proceedings of LTHs 8: e Pedagogiska Inspirationskonferens* (*PIK*). Lund, Sweden: Lunds University.

Boon NS (2019) Exploring STEM competences for the 21st century. Current and critical issues in curriculum. In *Learning and Assessment*, No. 30. IBE UNESCO.

Care E, Luo R (2016) *Assessment of transversal competencies: policy and practice in the Asia Pacific region*. Paris: UNESCO, Bangkok Office.

Conlon E (2008) The new engineer: between employability and social responsibility. *European Journal of Engineering Education* 33(2): 151–159.

Csíkszentmihályi M (2010) *Flow*. Budapest: Akadémiai Kiadó.

Czenky K (2006) Diploma, munkaerőpiac, munkanélküliség a hazai sajtó tükrében. (Diploma, labor market, unemployment in the reflection of the domestic press). In É Berde, K Czenky, Z Györgyi, T Híves, E Morvay, A Szerepi (eds.), *Diplomával a munkaerőpiacon*, 117–128. Budapest: Felsőoktatási Kutatóintézet.

Daruka M (2017) Miért van szükség az innovációk különböző fajtáira a felsőoktatásban? (Why are different types of innovations needed in higher education?) In É Bodnár, O Csillik, M Daruka, J Sass (eds.), *Varázsszer-e a tükrözött osztályterem?*, 6–13. Budapest: Budapesti Corvinus Egyetem.

Direito I, Pereira A, Olivera Duarte AM (2012) Engineering undergraduates' perceptions of soft skills: relations with self-efficacy and learning styles. *Procedia Social and Behavioral Sciences* 55: 843–851.

Duchon J (2021) *Gamifikáció az oktatásban.* (Gamification in education). Budapest: Typotop Kft.

Epstein RJ (2004) Learning from the problems of problem-based learning. *BMC Medical Education* 4: 1–7.

Freund T (2014, April 10-12) in: Szám Kati: Interjú Freund Tamás agykutatóval. (Interview with brain researcher Tamás Freund). In *Képmás*.

Frohmann R, Damsa A (2016) A gamifikáció (játékosítás) motivációs eszköztára az oktatásban. (The motivational toolbox of gamification in education). In *Új Pedagógiai Szemle*, 3–4.

Guzey, SS, Moore, TJ, Harwell, M (2016) Building up STEM: an analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering Education Research* 6(1): 11–29.

Híves T (2006) Munkaadói elvárások megjelenése az álláshirdetésekben. (Appearance of employer expectations in job advertisements). In É Berde, K Czenky, Z Györgyi, T Híves, E Morvay, A Szerepi (eds.), *Diplomával a munkaerőpiacon*, 73–87. Budapest: Felsőoktatási Kutatóintézet.

Holik I (2019) Preparing engineering students for the expectations of the labour market. *Turkish Online Journal of Educational Technology* 2: 254–263.

Holik I, Sanda ID (2022) *Features of practical engineering teacher education in Hungary*. In T Köhler, O Michler, H Hortsch, ME Auer (eds.), *Mobility for Smart Cities and Regional Development - Challenges for Higher Education,* 544–555. Springer International Publishing.

Hunya M (1998) *A disputa program.* (The dispute programme). Budapest: Soros Foundation.

Kagan S (2015) *Kooperatív tanulás.* (Cooperative learning). Budapest: Ökonet.

Karcsics É (2007) A versenyképes munkavállaló kompetenciái az Európai Unióban és Magyarországon. (Competencies of the competitive employee in the European Union and Hungary). *Európai Tükör* 3: 128–140.

Kefalis C, Drigas A (2019) Web based and online applications in STEM education. *International Journal of Engineering Pedagogy (iJEP)* 9(4): 76–85.

Kersánszki T, Nádai L (2020) The position of STEM higher education courses in the labor market. *International Journal of Engineering Pedagogy* 10(5): 62–76.

Kiss P (2010) Diplomás kompetenciaigény és munkával való elégedettség. (Demand for graduate competence and job satisfaction). In *Diplomás pályakövetés IV. Frissdiplomások 2010*, 105–130. Budapest: Educatio.

Kolmos A (2006) Future engineering skills, knowledge and identity. In Christensen et al. (eds.), *Engineering Science, Skills, and Bildung*, 165–186. Denmark: Aalborg University.

Lappalainen P (2009) Communication as part of the engineering skills set. *European Journal of Engineering Education* 34: 123–129.

Lukácsné Ujhegyi D (2013) *Transzverzális kompetencia.* (Transversal competency). Pécs: Pécsi Tudományegyetem.

Módné TJ, Pogátsnik M, Kersánszki T (2022) improving soft skills and motivation with gamification in engineering education. In ME Auer, H Hortsch, O Michler, T Köhler (eds.), *Mobility for Smart Cities and Regional Development - Challenges for Higher Education*: Proceedings of the 24th International Conference on Interactive Collaborative Learning, 823–834. Cham: Springer International Publishing.

Nagy E (2020) Robotok az oktatási-nevelési folyamatokban. (Robots in educational processes). *Képzés és gyakorlat: Training and Practice* 18 (3–4): 176–186.

Nagy L, Nagy M (2016) Kutatásalapú tanítás-tanulás a biológiaoktatásban és a biológiatanár-képzésben. (Research-based learning in the teaching of biology and the training of biology teachers). *Iskolakultúra* 3: 57–69.

Noonan R (2017) *STEM jobs: 2017 update*. ESA Issue Brief #02-17. Washington, DC: Office of the Chief Economist, Economics and Statistics Administration, U.S. Department of Commerce.

Novák J (2020) Environmentally conscious education. *Critical Infrastructure Protection. Review* (9) 1–6.

Pénzes IR, László É, Pólya É, Szűcs RS, Földi K, Horváth M (2012) Munkaerő-piaci kutatáson alapuló képzésinnováció a Szolnoki Főiskolán. (Training innovation based on labour market research at the College of Szolnok). In *Szolnoki Tudományos Közlemények* XVI, Szolnok.

Polónyi I (2007) A gazdaság és a felsőoktatás kapcsolata – egy empirikus kutatás néhány tanulsága. (The relationship of the economy and higher education – Some lessons drawn from an empirical study). In A Somogyi (ed.), *VI. Nemzetközi Konferencia a közgazdász képzés megkezdésének 20. évfordulója alkalmából*. 1. kötet (6th International Conference on the 20th anniversary of the start of economist training, vol. 1), 248–266. Miskolc: Miskolci Egyetem (University of Miskolc).

Säävälä T (2011) Key competences for lifelong learning – the European framework. In I Vágó (ed.), *Az európai polgár kompetenciái.* Budapest: Oktatáskutató és Fejlesztő Intézet (Institute of Educational Research and Development).

Schoenfeld, AH (2006) Design experiments. In PB Elmore, G Camilli, J Green (eds.), *Handbook of complementary methods in education research*, 193–206. Washington, DC & Mahwah, NJ: American Educational Research Association and Lawrence Erlbaum Associates.

Schomburg H (2007) The professional success of higher education graduates. *European Journal of Education* 42: 35–57.

Schulz B (2008) The importance of soft skills: education beyond academic knowledge. *NAWA Journal of Language and Communication* 2/1: 146–154.

Seetha S (2013) Necessity of soft skills training for students and professionals. *International Journal of Engineering, Business and Enterprise Applications* 4/2: 171–174.

Selmeczy I (2006) *Az üzleti szféra felsőfokú végzettségű pályakezdők iránti kereslete, ennek várható alakulása és a pályakezdők tudásával való elégedettség 2005-ben. Egy empirikus vállalati felvétel és szakértői interjúk elemzése*. (The business sector's demand for career starters with higher education, its expected development and satisfaction with the knowledge of career starters in 2005. Analysis of an empirical company survey and expert interviews). Budapest: Magyar Kereskedelmi és Iparkamara.

Sheffield R, Koul R (2021) Investigating learning in a STEM makerspace: India case study. *Journal of Physics: Conference Series* 1882: 012141

Smith KA, Sheppard SD, Johnson DW, Johnson RT (2005) Pedagogies of engagement: classroom-based practices. *Journal of Engineering Education* 94: 87–101.

Szabó CsM, Bartal Zs (2020) Munkaerőpiaci elvárások a leendő mérnökök jövőképének tükrében. (Appearance of the labour market requirements in engineer students' future prospects). *Journal of Applied Technical and Educational Sciences* (*JATES*) 10(1).

Williamson JM, Lounsbury JW, Hanc LD (2013) Key personality traits of engineers for innovation and technology development. *Journal of Engineering and Technology Management* 30(2): 157–168.

Wolhuter CC (2020) Relevance, rigour and restructuring: the 3Rs as a compass for a community of scholars in need of direction. In CC Wolhuter (ed.), *Education Studies in South Africa: The Quest for Relevance, Rigour and Restructuring*, 1–21. Cape Town: AOSIS.

World Economic Forum (2020) *The future of jobs Report 2020*. World Economic Forum.