USE OF ICT IN MATHEMATICS STUDIES TO DEVELOP DIGITAL SKILLS OF UNDERGRADUATE ENGINEERING STUDENTS

Eve Aruvee[1], Anna Vintere[2]
[1]Estonian University of Life Sciences, Estonia;
[2]Latvia University of Life Sciences and Technologies, Latvia
eve.aruvee@emu.ee, anna.vintere@llu.lv

Abstract. Several studies suggest that industrial infrastructure and education need to be adapted in line with the 4th Industrial Revolution. In education, on the one hand, schools, training and university programs need to be adoptive and, on the other hand, an entrepreneurial approach is needed to increase the information technologies and innovation skills of the workforce. To sustain economic growth, emerging economies need education and training programs to develop skills, especially digital, which are increasingly in demand in the labour market. Digital competence is not just the ability to surf the Internet, it can be broken down into many smaller components. It should be also noted that digital competence, can be seen also as a transversal competence, it also helps develop other essential skills, such as communication, language skills or basic knowledge in mathematics or science. The European Commission has developed the Digital Competences Framework for Europeans (DigComp), which is divided into five areas: information and data literacy; communication and cooperation; digital content creation; safety; and problem solving. The empirical part of the study includes a comparative analysis of the use of technology in mathematics studies at the Latvia University of Life Sciences and Technologies and the Estonian University of Life Sciences, and a student survey to assess the development of digital competencies in mathematics studies at the university by five components identified in DigComp, as well as to identify which e-learning tools (informative and interactive) and internet resources looking for specific information or using other mathematics software besides MatLab or MathCad are included in the course. The analysis of students' digital skills shows that these are quite good. However, the biggest problems for students were solving problems, such as storing files in the cloud, editing videos/photos, solving technical problems related to studying mathematics, and solving security problems.

Keywords: digital literacy, communication, cooperation, mathematics studies, problem solving.

Introduction

The rapid development and use of information and communication technologies (ICT) has led to the Fourth Industrial Revolution, which marks a fundamental change in every industrial sector, economy and human resource. The Fourth Industrial Revolution is mainly concerned with the use of engineering knowledge for the use of information technology for the deployment of the Internet of Things [1]. Manufacturing enterprises are currently facing substantial challenges with regard also to Industrial Internet, Cyber Physical Systems or Cloud-based Manufacturing, Smart Manufacturing, as well as manufacturing processes that combine intelligent machines with humans to create high-skill value chains [2].

The introduction of new technologies affects the labour market, as the 4th Industrial Revolution requires specific knowledge and skills. An important role is played by the intelligent data collection and interpretation, the correct decision making, and their timely implementation because of using the most advanced technologies, which allows faster data collection and interpretation procedures [3].

Therefore, according to the World Economic Forum 50% of all employees will need reskilling by 2025, as adoption of technology increases. The World Economic Forum updated the top 10 skills supporting the development of future professions for 2025, which are necessary in the conditions of the 4th Industrial Revolution [4]:

- problem-solving: analytical thinking and innovation; complex problem-solving; critical thinking and analysis; creativity, originality and initiative; reasoning, problem-solving and ideation;
- self-management: resilience, stress tolerance and flexibility;
- working with people: leadership and social influence;
- technology use and development: technology use, monitoring and control; technology design and programming.

It is already identified that such problem-solving skills as analytical skills, critical thinking, systemic thinking, problem solving skills, logical thinking, creativity and decision-making skills can be

DOI: 10.22616/ERDev.2022.21.TF291

developed in mathematics [5; 6]. Mathematics studies also contribute to the development of digital competences. In general, the usage of ICT in higher education, including a mathematics course, covers three main areas: computer hardware, the operating system, and special software. Students must be able to adapt their communication style to new technologies and be able to collaborate in a virtual environment [7]. The use of information and communication technologies is a symbol of a new historical time in education, characterized by an effort to meet the needs of students to be able to learn without time and space constraints. In addition, ICT is changing thinking patterns, enriching existing educational models and providing new training models [8].

Digital technologies in the universities of both authors of this study in mathematics studies are used to independently learn the available informative and interactive e-materials, solve problems with mathematics software, find the necessary information, collaborate online, etc. In both universities, the e-learning environment is based on the course management system Moodle, which contains various study materials that were used as a supplement to full-time studies, as well as for organizing students' independent work, assessment of knowledge and skills, including so-called non-educational activities, such as communication between students and teachers, recording grades and test results online, changing schedules and uploading students' homework, etc. [9]. Thus, to contribute to the development of digital skills required for future professions in the context of the Fourth Industrial Revolution, the aim of this study is to assess the development of digital competencies of of undergraduate engineering students in mathematics studies.

Materials and methods

The methodology of this study is based on "Digital Competences Framework for Europeans" (DigComp), offered by the European Commission, which is divided into five areas [10].

- **Information and data literacy**: to articulate information needs, to locate and retrieve digital data, information and content. To judge the relevance of the source and its content. To store, manage, and organise digital data, information and content.
- **Communication and collaboration**: to interact, communicate and collaborate through digital technologies while being aware of cultural and generational diversity. To participate in society through public and private digital services and participatory citizenship. To manage one's digital identity and reputation.
- **Digital content creation**: to create and edit digital content. To improve and integrate information and content into an existing body of knowledge while understanding how copyright and licences are to be applied. To know how to give understandable instructions for a computer system.
- **Safety**: to protect devices, content, personal data and privacy in digital environments. To protect physical and psychological health, and to be aware of digital technologies for social well-being and social inclusion. To be aware of the environmental impact of digital technologies and their use.
- **Problem solving**: to identify needs and problems, and to resolve conceptual problems and problem situations in digital environments. To use digital tools to innovate processes and products. To keep up-to-date with the digital evolution.

This document claims that being digitally competent means using digital technologies in a confident and safe way for various purposes such as working, getting a job, learning, shopping online, obtaining health information, being included and participating in society, entertainment, etc. [10].

Today, digital competences are no longer just about access to and use of information communication technologies, they are also about ICT knowledge, skills and attitudes. It should be noted that digital competence, it can be seen also as a transversal competence, helps develop other essential skills, such as communication, language skills or basic knowledge in mathematics or science [11].

Based on digital competence areas identified in the EC document "Digital Competences Framework for Europeans (DigComp)", a questionnaire for undergraduate engineering students was created, applying the competencies shown in Figure 1 to the specifics of the mathematics study course.

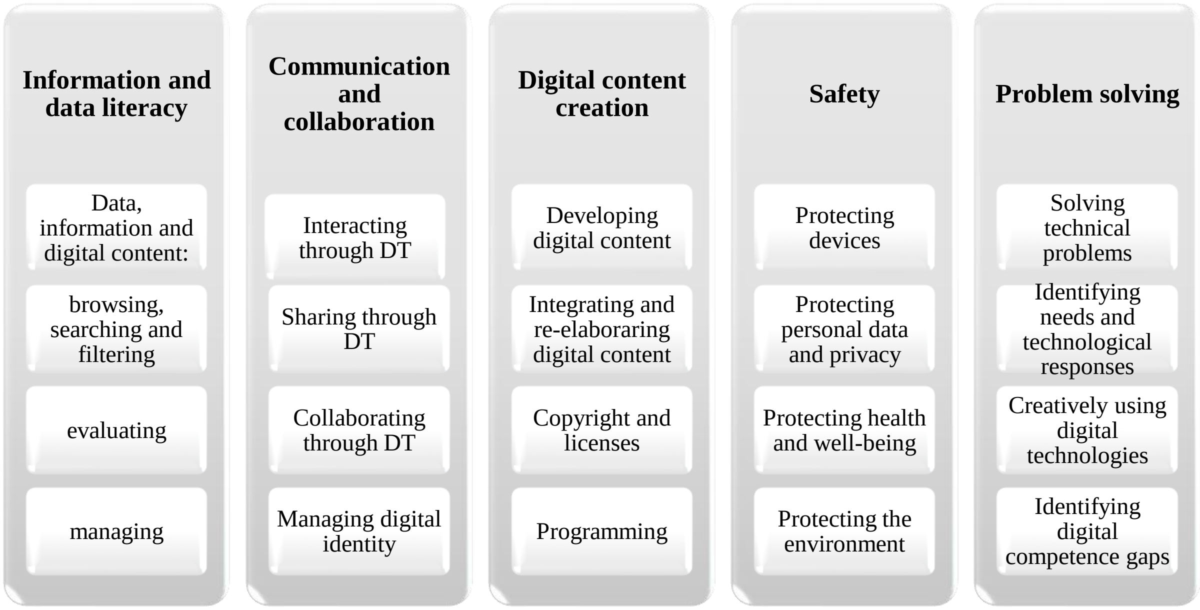

Fig. 1. **Digital competence areas**

All questions had four possible responses: *1. I can do that; 2. I can do it with the help of others; 3. I cannot do that; 4. To do this, I often search for information on the Internet*.

Empirical research includes a survey of undergraduate forestry, agricultural, civil engineering students at the Latvia University of Life Sciences and Technologies (65 students), and undergraduate civil engineering and technology students at the Estonian University of Life Sciences (60 students) and identification of digital competence areas in IT technologies. The questionnaires are available at: https://forms.gle/wAk6S6aSB7EKwELW7 (in Latvian) and https://forms.gle/Vc2uAwBoosSB8Ur87 (in Estonian). Of both universities, most of the study year 1 and 2 students from Latvia, respectively, 46 and 16 and from Estonia 22 and 31 students responded to the survey (see Table 1).

Table 1

Number of students who responded to the survey by gender and academic year

Latvia				Estonia			
Study year	**Man**	**Woman**	**Total**	**Study year**	**Man**	**Woman**	**Total**
1	33	13	46	1	15	7	22
2	11	5	16	2	26	5	31
3	2	-	2	3	5	1	6
4	-	1	1	4	1	-	1
Total	46	19	65	-	47	13	60

The self-assessment method was used in the study. According to educational research, the self-assessment method is used to identify strengths and weaknesses and make improvements in higher education performance [12].

Results and discussion

The first part of the questionnaire was "**Abilities related to information and data literacy**". Our analysis revealed that most students from both Latvia and Estonia are able to do all the activities (Table 2). About 1/3 of students from both countries seek help from the Internet or use the help of others related to their studies in mathematics. Students from both countries also know how to work with files, and how to copy and save files. However, more Estonian students have been involved in storing files in the cloud.

Table 2

Abilities related to information and data literacy

	Latvia				Estonia			
Ability	**1**	***2***	**3**	**4**	**1**	***2***	**3**	**4**
Search for information related to math studies	40	7	1	17	39	9	0	12
Find the appropriate math software on the Internet	31	9	6	19	33	15	1	11
Use the available math software to better understand the topic	35	16	6	9	33	6	1	19
Searching the Internet for materials to better understand mathematics topics	43	9	3	11	47	6	0	7
Use available math software to solve homework	34	16	7	9	45	6	0	9
Copy files or folders	60	4	1	1	59	0	0	1
Save files to the computer	64	2	0	0	60	0	0	0
Save files to the cloud	53	6	3	4	58	1	1	0

The second part of the questionnaire was "**Abilities related to digital problem solving**" where abilities are defined according to the "Digital Competences Framework for Europeans (DigComp)" [10]. Analysis shows (Table 3) that students from both countries answered to the first four questions that they know how to do this activity. To the last two questions, only half answered that they know how to solve technical problems that arise during their studies of mathematics and they are creative in using digital technologies related to studying mathematics (i.e. they can find workarounds to solve difficult problems). To solve these two questions, both Latvian and Estonian students are either seeking the help of others or seeking help on the Internet.

Table 3

Abilities related to digital problem solving

	Latvia				Estonia			
Ability	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Move files between different devices	56	6	1	1	58	1	0	1
Install apps/software	58	5	0	2	55	4	0	1
Change software settings	51	9	4	1	50	3	0	7
Participate in online education	62	3	0	0	51	4	0	5
Ability to solve technical problems in the math study process	31	22	2	10	28	22	0	9
Creativity in the use of digital technologies in math studies	29	17	7	11	31	16	4	8

The third part of the questionnaire was "**Activities related to communication and collaboration**". From the table below (Table 4), we can see that most students from both Latvia and Estonia know how to communicate with the teacher using social networks. However, the most difficult question is for 8% of Latvian and 12% of Estonian students to use voice/video call, that provides instant feedback, for example during distance learning, as well as ensuring that students work together through group work or a joint project.

The fourth part of the questionnaire was "**Activities related to digital content creation**". Latvian students use the computer package Matlab in their mathematics studies, but Estonian students use MathCad. By analysing this activity, we can see that there are the biggest differences between Latvian and Estonian students (Table 5). We can see that most students from Estonia know how to solve mathematics tasks with the tools of MathCad. However, the difficult questions are to use or write mathematical expressions in MathCad for 13% of Estonian students, they need to ask for help of others. Many students (22%) face difficulties in editing audio/photo/video files. Based on the answers, it seems that the use of MatLab is quite complicated for Latvian students. Only 1/3 of students do it well. Others need to either ask for help from fellow students or seek help on the Internet. 13% of students say they do not know how to use MatLab at all.

Table 4

Activities related to digital content creation

	Latvia				Estonia			
Ability	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Communication with the math teacher using the study system	22	20	8	15	50	7	0	3
Communication with the teacher using social networks (Facebook, WhatsApp, etc.)	20	20	9	16	47	8	0	4
Ability to use voice/video call	26	15	9	14	52	3	0	5
Collaboration with course members in math studies using social networks (Facebook, WhatsApp, etc.)	44	9	6	7	43	4	0	13
Online collaboration with course members in math studies	55	6	1	4	58	1	0	1

Table 5

Activities related to digital content creation

	Latvia				Estonia			
Ability to	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Use math software MatLab/MathCad	22	20	8	15	50	7	0	3
Write mathematical expressions in MatLab/MathCad	20	20	9	16	47	8	0	4
Save the work created in MatLab/MathCad in different formats	26	15	9	14	52	3	0	5
Edit audio/photo/video files	44	9	6	7	43	4	0	13
Upload your own content online	55	6	1	4	58	1	0	1

The fifth part of the questionnaire was "**Abilities related to safety**". Most students (85%) from both countries know how to protect their data, their online privacy, how to use security tools and how to recognize people with bad intentions on the Internet (Table 6). About 5% of Latvian students and 3% of Estonian students know little about security issues, they do not know how to solve these. Only 50% of students know how to solve problems in cyber defence, only 10% of students said "I cannot do that", the rest know how to do it with the help of others or searching for information on the Internet.

Table 6

Activities related to safety

	Latvia				Estonia			
Ability to	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Protect your personal data and privacy on the Internet	56	3	1	5	54	2	1	3
Use security tools	51	6	4	5	49	3	1	7
Identify people with bad goals on the Internet	58	4	3	1	53	2	2	3
Problem-solving skills in cyber defence	39	10	8	9	32	13	5	10

Conclusions

1. The digital skills of students are quite good.
2. Only a few students may see shortcomings in some abilities defined in the EC document "Digital Competences Framework for Europeans (DigComp).
3. The vast majority of undergraduate engineering students are able to find information related to both mathematics studies and for better understanding of mathematics topics.
4. More than half of the students (i.e. 53% of Latvians and 78% of Estonians) can find a relevant mathematics program, which ~~is~~ can also be used to solve homework.

5. Matlab software is included in the mathematics study program in Latvia, but MathCad in Estonia. As it is known, MatLab is a more complex program and has many advantages compared to MathCad. The survey results show that the use of MatLab is quite complicated for Latvian students as only 1/3 of students do it well. The results show that it is difficult to write mathematical expressions in MathCad for 13% of Estonian students, but 13% of Latvians do not know how to use Matlab at all, which indicates that more investment is needed in learning how to use this software.
6. The most attention should be paid to solving security problems. According to the authors of this article, it would also be necessary to include these issues in university curriculum.
7. The empirical part of the research uses a self-assessment method. Therefore, the results are based on the respondents' opinion and can be used to identify problems, which needs to be addressed, as well as areas where deeper research is needed.

Author contributions:

Example: Conceptualization, A.V.; methodology, A.V. and E.A. software, E.A.; validation, A.V. and E.A; formal analysis, E.A.; investigation, A.V. and E.A.; data curation, A.V. and E.A.; writing – original draft preparation, E.A.; writing – review and editing, A.V.; visualization, E.A.; project administration, A.V.; funding acquisition, E.A. All authors have read and agreed to the published version of the manuscript.

References

[1] Wang S., Wan J., Li D., Zhang C. Implementing Smart Factory of Industrie 4.0: An Outlook. Hindawi Publishing Corporation, International Journal of Distributed Sensor Networks, Volume 2016, Article ID 3159805, 10 p.
[2] Schumacher A., Erol S., Sihn W. A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP, 52, 2016, pp. 161-166.
[3] Qin J., Liu Y., Grosvenor R. A Categorical Framework of Manufacturing for Industry 4.0 and Beyond. Procedia CIRP, 52, 2016, pp. 173-178.
[4] World Economic Forum. The Future of Jobs, Report 2020, October 2020.
[5] Vintere A., Macaitiene R. Mathematics education development in line with the trends of sustainable development: Experience within the "MATnet". 19th International conference on Applied Mathematics, APLIMAT 2020: proceedings, B-ratislava, Slovakia, February 4-6, 2020, pp.1119-1130.
[6] Vintere A. Pedagogical approaches to teaching mathematics for building analytical, problem solving skills and critical thinking. 13th International Technology, Education and Development Conference (INTED 2019): proceedings, Valencia, Spain, March 11th-13th, 2019, pp. 6869-6873.
[7] Torres-Coronas T., Vidal-Blasco M.A. Students and employers' perception about the development of digital skills in higher education. Revista de Educación, 367. January-March 2015, pp. 63-89.
[8] Sridevi J., Bala Krishnan C., Senthil Kumar K. Information and Communication Technology (ICT) in Higher Education: Advantages, Disadvantages of Applying E-Learning to Students. International Journal of Pure and Applied Mathematics, Volume 117 No. 15, 2017, pp. 177-182.
[9] Vintere A., Aruvee E., Rimkuviene D. A comparative study of the organization of a remote mathematics study process during the Covid-19 pandemic. Mobility for Smart Cities and Regional Development - Challenges for Higher Education: proceedings of the 24th International conference on Interactive Collaborative Learning (ICL2021), Dresden, Germany, September 22-24, 2021, Technische Universität Dresden, India : Springer Nature, 2022, pp. 7631-7636.
[10] DigComp 2.0: The Digital Competence Framework for Citizens. [online] [03.01.2022]. Available at https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework.
[11] Zeidmane A., Vintere A. A case study of students' views on the digital skills needed for the labour market. 18th International conference on Cognition and exploratory learning in digital age CELDA 2021, Virtual, 13-15 October, 2021, International Association for the Development of the Information Society - Virtual, 2021.
[12] Andrade, H., Valtcheva, A.: Promoting learning and achievement through self-assessment. Theory into Practice, 48, 2009, pp. 12-19.