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The innovative use of ICT in STEM teacher training programmes at the University of Ljubljana

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ABSTRACT: To support the professional development of future teachers in the use of ICT, the project entitled *ICT in Teacher Training Study Programmes* at the University of Ljubljana was launched and lasted from April 2017 to September 2018. The project involved 37 pilot-renewals in the area of STEM teacher training programmes. Information was gathered about ICT-supported innovative teaching approaches based on the analysis of the reports of 54 university teachers and assistants in STEM teaching, after the conclusion of their pilot-renewals. The reports about STEM pilot-renewals were studied based on the theoretical framework of the SAMR model that identifies four degrees of classroom technology integration (substitution, augmentation, modification and redefinition). The results indicate the current state regarding the use of ICT in the STEM teacher training study programmes at the University of Ljubljana and point to development possibilities for the future.

INTRODUCTION

The increasing presence and use of technology in classrooms makes it necessary to transform teaching in response. Technology can raise motivation, increase interest among students and enhance learning. Therefore, teachers are encouraged to use various types of technology [1] in order to be effective in the information-rich 21st Century [2]. In higher education there are massive open on-line courses (MOOCS) [3][4], mobile-flipped learning [5] and 3D computer-aided design systems [6]. Teachers need the skills and knowledge of technology to design technology-rich learning experiences for students [7]. Ultimately teaching and learning will be transformed by the technology that students use daily [2]. Digital technologies enable instant information access and global communication [8].

Workers today have to be creative, flexible and information-aware. Memorisation, repetition and basic comprehension are insufficient. There is a need to develop higher-order skills, such as critical and creative thinking, elaboration and evaluation [9]. Integrating technology into the learning process can be difficult for teachers. A barrier is the teacher's competency in the technology [10]. Teachers often do not feel sufficiently skilled to use technology in the classroom and may not appreciate its value. But acquiring the knowledge and skills of technology is a time-intensive activity [11]. Furthermore, the use of technology itself does not guarantee positive results in the quality of learning. The appropriate use of ICT depends on a teacher's pedagogical and technological competency and their inter-relationship [1][11][12]. To be properly used, technological, pedagogical, and content knowledge and skills have to be integrated during pre-service education [10].

Different information and communication technologies (ICT) can be used for learning and teaching [13]. The substitution, augmentation, modification and redefinition (SAMR) model, which gained popularity in 2012, provides a framework for teachers to integrate emerging technologies into their daily lessons [12]. The SAMR model is an approach to select, use and evaluate technology in education. The SAMR model identifies four levels of classroom technology, which are grouped into two stages [14]:

- *Substitution* - technology acts as a direct substitute, with no functional change.
- *Augmentation* - technology acts as a direct substitute, with functional improvement.

} Enhancement

- *Modification* - technology allows for significant task redesign.
- *Redefinition* - technology allows for the creation of new ideas.

} Transformation

Using ICT in the enhancement stage is ineffective in promoting deep learning, creativity, communication, collaboration and critical thinking. Deep learning, flexibility, critical thinking, problem solving, communication and collaborative abilities can be developed by the use of ICT in the *transformation* stage [15].

According to Fraillon et al [16] the main difficulties for technology-driven education in Slovenian schools can be summed up as:

1) lack of ICT to enhance motivation and creativity;
2) little theory-driven technology practice;
3) lack of the use of ICT to enrich higher cognitive thinking;
4) more that 40 per cent of teachers still use ICT in intuitive ways;
5) teachers do not use ICT-supported methods and strategies for teaching/learning, e.g. reverse engineering, augmented experimental work, mobile learning, design thinking [16].

A vision of technology integration into classrooms includes theory-driven technology practice (meaningful learning), learning innovation through technology, technology as career facilitator and contextual accommodation using technology.

METHOD

Context

The development of ICT skills by future teachers during their study at university is necessary for the successful implementation of ICT-supported innovative approaches, and effective teaching and learning in their future school practice. To support the future teachers' development at the University of Ljubljana, Slovenia, was a project entitled *ICT in Teacher Training Study Programmes,* which ran from April 2017 to September 2018. The overall project included the renewal of 48 pedagogical study programmes at the first or second Bologna levels (Bachelor's/Master's) at nine faculties of the University of Ljubljana. This involved pilot-renewals of the subjects/modules/programmes based on the didactic implementation of ICT in the teaching materials; the improvement of ICT-supported teaching and learning; and the development of pedagogical models. The main aim of this study was to investigate the pilot-renewals in STEM areas and how these maps to the SAMR model.

The following research questions (RQ) were defined:

- RQ1: Which ICT-supported activities for future teachers were included in the implemented pilot-renewals?
- RQ2: On which level of the SAMR model are positioned the ICT-supported activities for future teachers in the implemented pilot-renewals?

Research Sample

The research sample consisted of 54 STEM area university teachers and assistants (34 female, 20 male) who participated in the pilot-renewals in the project entitled *ICT in Teacher Training Study Programmes* at the University of Ljubljana.

Pilot-renewals

In STEM teacher training programmes there were 37 pilot-renewals in the following subject-areas for elementary and secondary teacher education:

- engineering and technology;
- computer studies;
- mathematics;
- biology;
- chemistry;
- physics;
- science.

All pilot-renewals took place in the academic year 2017/18 at the University of Ljubljana. Each pilot-renewal included from five to 75 hours of upgraded activities. Ten to 78 out of 1,117 future teachers participated. Each of the pilot-renewals included from one to eight new ICT-supported activities.

Data Collection

After the conclusion of the pilot-renewals, the university teachers and assistants filed pilot-renewal reports. Included in this article is the following information from the pilot-renewal reports:

- descriptive data - course, study programme of future teachers, number of participating future teachers, upgraded activities;
- content data - purpose of the activities in the pilot-renewal, description of the activities in the pilot-renewal.

Data Analysis

To derive the SAMR level of the implemented activities the pilot-renewals were analysed using Hilton's categorisation framework [12]. Two researchers separately analysed the content part of eight of the pilot-renewal reports (about 20% of the total) to develop a rubric for the evaluation of the SAMR level.

Each researcher independently proposed categories of ICT-supported activities and the SAMR level. Finally, to obviate bias, through discussion, these researchers came to the final version of the rubric. This enabled a 95% reliability rating for the categorisation of the analysed items. The developed rubric was then used in the analysis of the entire set of pilot-renewal reports. The categorisation was implemented with regard to the prevailing activity, in particular parts of the pilot-renewals.

RESULTS

ICT-supported Activities in Pilot-renewals (Related to RQ1)

Various kinds of ICT-supported activities were included in the pilot-renewals by the university teachers and assistants in the STEM area (see Table 1 and Table 2). Most frequently used ICT-supported activities for future teachers were related to:

1) *Experimental work* (f_a(%) = 19.59, f_a = 19), which was included in one-third of pilot-renewals (f_{pr}(%) = 32.43, f_{pr} = 12);
2) *Visualisation of particular phenomena* (f_a(%) = 18.56, f_a = 18), which were included in half of pilot-renewals (f_{pr}(%) = 48.65, f_{pr} = 18);
3) *Formative assessment* (f_a(%) = 17.53, f_a = 17), which were included in more than one-third of pilot-renewals (f_{pr}(%) = 37.84, f_{pr} = 14);
4) *Learning management system and platforms* (f_a(%) = 10.31, f_a = 10), which were included in less than one-third of pilot-renewals (f_{pr}(%) = 27.03, f_{pr} = 10).

Table 1: ICT-supported activities.

Description of future teacher's activities	Activities		Pilot-renewals	
	f_a	f_a (%)	f_{pr}	f_{pr} (%)
Experimental work	19	19.59	12	32.43
Visualisation of particular phenomena	18	18.56	18	48.65
Formative assessment	17	17.53	14	37.84
Learning management system and platforms	10	10.31	10	27.03
Presentations	7	7.22	7	18.92
Educational games and digital stories	7	7.22	5	13.51
Technological modelling	5	5.15	5	13.51
Coding	5	5.15	4	10.81
Flipped classroom	3	3.09	3	8.11
Data analysis	3	3.09	3	8.11
Project-based learning	3	3.09	3	8.11

Table 2: Proportions of different types of ICT-supported activity, from the future teacher's perspective.

Description of future teacher's activities	f_a	f_a (%)
Experimental work	19	19.59
Observation of the use of *sensors with software* for capturing, presenting and analysing experimental data	1	1.03
Use of *sensors with software* for capturing, presenting and analysing experimental data	3	3.09
Evaluation of *sensors with software* for capturing, presenting and analysing experimental data	1	1.03
Development of meaningful implementation of *sensors with software* for capturing, presenting and analysing experimental data	1	1.03
Use of *mobile application* for capturing, presenting and analysing experimental data	4	4.12
Development of a meaningful implementation of *mobile applications* for capturing, presenting and analysing experimental data	1	1.03
Evaluation of *various sensors and mobile applications* for capturing, presenting and analysing experimental data	1	1.03
Observation of the use of *microscopy*	1	1.03
Use of *microscopy*	2	2.06
Use of *microscopy and presentation of results*	2	2.06
Use of *ICT in support of reporting about experimental work*	1	1.03
Evaluation of *ICT in support of reporting about experimental work*	1	1.03

From Table 2 and Table 3 further details on particular activities can be inferred. Activities related to *experimental work* reveal the future teachers' use of mobile applications for capturing, presenting and analysing experimental data (f_a(%) = 4.12, f_a = 4). Most frequently implemented activities related to *visualisation of particular phenomena* were observations of the use of specific software for representing phenomena (f_a(%) = 5.15, f_a = 5) and evaluation of various tools for the preparation of concept maps (f_a(%) = 4.12, f_a = 4).

The highest proportion of activities related to *formative assessment* was the use of response systems (f_a(%) = 11.34, f_a = 11), which was also the most frequently used specific activity in all pilot-renewals. Within *learning management system and platforms*, use of learning management systems was significant (f_a(%) = 8.25, f_a = 8). Frequently used specific activities were also related to *presentations*; more specifically was the use of presentational software (f_a(%) = 4.12, f_a = 4). Several other activities were reported with lower frequencies.

Table 3: Proportions of different types of ICT-supported activity, in detail.

Description of future teacher's activities	f_a	f_a (%)
Visualisation of particular phenomena	18	18.56
Observation of the use of *specific software* for representing particular phenomena	5	5.15
Use of *specific software* for representing particular phenomena	1	1.03
Development of meaningful implementation of *specific software* for representing particular phenomena	1	1.03
Development of meaningful implementation of *specific and general software* for representing particular phenomena and *peer assessment*	1	1.03
Observation of the use of *videos* for representing particular phenomena	1	1.03
Evaluation of *videos* for representing particular phenomena	1	1.03
Evaluation of various tools for preparation of *concept maps*	4	4.12
Development of meaningful implementation of *QR-codes*	2	2.06
Development of meaningful implementation of *digital dichotomous identification keys*	2	2.06
Formative assessment	17	17.53
Observation of the use of *response systems*	11	11.34
Evaluation of *response systems*	2	2.06
Development of meaningful implementation of *response systems*	1	1.03
Development of meaningful implementation of *specific and general software* for representing particular phenomena	1	1.03
Observation of the use of *collection of learning materials* for representing particular phenomena	2	2.06
Learning management system and platforms	10	10.31
Use of *learning management system*	8	8.25
Use of *learning platform*	2	2.06
Presentations	7	7.22
Observation of the use of *presentational software*	4	4.12
Use of *presentational software*	3	3.09
Educational games and digital stories	7	7.22
Observation of the use of *educational games*	1	1.03
Use of ICT in *educational games*	2	2.06
Development of meaningful implementation of *educational games*	2	2.06
Development of meaningful implementation of *digital stories*	2	2.06
Technological modelling	5	5.15
Use of *3D printing*	2	2.06
Development of meaningful implementation of *3D printing*	1	1.03
Observation of the use of *software for technological modelling*	1	1.03
Use of *software for technological modelling*	1	1.03
Coding	5	5.15
Use of *software for coding*	2	2.06
Development of meaningful implementation of *software for coding*	2	2.06
Development of meaningful implementation of *software for coding and presentation of results*	1	1.03
Flipped classroom	3	3.09
Observation of the use of *ICT in support of flipped classroom*	3	3.09
Data analysis	3	3.09
Use of *data analysis software*	3	3.09
Project-based learning	3	3.09
Use of *ICT in support of monitoring and development of project work*	1	1.03
Development of meaningful implementation of *specific and general software* for representing particular phenomena	2	2.06

The SAMR Level of ICT-supported Activities in the Pilot-renewals (Related to RQ2)

Various SAMR model levels were represented in the pilot-renewal activities (see Table 4 and Table 5). Most frequently used ICT-supported activities were of the *augmentation level* (f_a(%) = 53.61, f_a = 52), which were included in more than half of pilot-renewals (f_{pr}(%) = 59.46, f_{pr} = 22).

Table 4: SAMR model levels - general.

SAMR level	Activities		Pilot-renewals	
	f_a	f_a (%)	f_{pr}	f_{pr} (%)
Substitution	0	0.00	0	0.00
Augmentation	52	53.61	22	59.46
Modification	27	27.84	20	54.05
Redefinition	18	18.56	12	32.43

Less frequently implemented were activities of the *modification level* (f_a(%) = 27.84, f_a = 27), which were included in more than half of pilot-renewals (f_{pr}(%) = 54.05, f_{pr} = 20) and activities on the *redefinition level* (f_a(%) = 18.56, f_a = 18), which were included in one-third of pilot-renewals (f_{pr}(%) = 32.43, f_{pr} = 12). There was no activity in any pilot-renewal categorised as the *substitution level* (f_a(%) = 17.53, f_a = 17, f_{pr}(%) = 0.00, f_{pr}= 0).

Table 5 displays further details about activities related to different levels of the SAMR model. Activities on the *augmentation level*, the future teacher's use of response systems, the use of learning management system and the use of specific software for representing particular phenomena are significant (f_a(%) = 11.34, f_a = 11; f_a(%) = 7.22, f_a = 7; f_a(%) = 5.15, f_a = 5, respectively).

Table 5: SAMR model levels - details.

Description of future teacher's activities	f_a	f_a (%)
SAMR level A	52	53.61
Observation of the use of *response systems*	11	11.34
Observation of the use of *collection of learning materials* for representing particular phenomena	2	2.06
Observation of the use of *sensors with software* for capturing, presenting and analysing experimental data	1	1.03
Observation of the use of *microscopy*	1	1.03
Use of *microscopy*	4	4.12
Observation of the use of *presentational software*	4	4.12
Use of *presentational software*	3	3.09
Use of *3D printing*	1	1.03
Observation of the use of *software for technological modelling*	1	1.03
Use of *software for technological modelling*	1	1.03
Use of *learning management system*	7	7.22
Use of *learning platform*	1	1.03
Observation of the use of *ICT in support of flipped classroom*	3	3.09
Use of *software for coding*	2	2.06
Observation of the use of *educational games*	1	1.03
Use of *ICT in educational games*	2	2.06
Observation of the use of *specific software* for representing particular phenomena	5	5.15
Use of *specific software* for representing particular phenomena	1	1.03
Observation of the use of *videos* for representing particular phenomena	1	1.03
SAMR level M	27	27.84
Evaluation of *response systems*	2	2.06
Use of *sensors with software* for capturing, presenting and analysing experimental data	3	3.09
Evaluation of *sensors with software* for capturing, presenting and analysing experimental data	1	1.03
Use of *mobile application* for capturing, presenting and analysing experimental data	4	4.12
Evaluation of *various sensors and mobile applications* for capturing, presenting and analysing experimental data	1	1.03
Use of *ICT in support of reporting about experimental work*	1	1.03
Evaluation of *ICT in support of reporting about experimental work*	1	1.03
Evaluation of various tools for preparation of *concept maps*	4	4.12
Use of *3D printing*	1	1.03
Development of meaningful implementation of *digital dichotomous identification keys*	2	2.06
Use of *learning management system*	1	1.03

Description of future teacher's activities	f_a	f_a (%)
Use of *learning platform*	1	1.03
Use of *data analysis software*	3	3.09
Development of meaningful implementation of *specific software* for representing particular phenomena	1	1.03
Evaluation of *videos* for representing particular phenomena	1	1.03
SAMR level R	18	18.56
Development of meaningful implementation of *response systems*	1	1.03
Development of meaningful implementation of *specific and general software* for representing particular phenomena	1	1.03
Development of meaningful implementation of *sensors with software* for capturing, presenting and analysing experimental data	1	1.03
Development of meaningful implementation of *mobile applications* for capturing, presenting and analysing experimental data	1	1.03
Development of meaningful implementation of *3D printing*	1	1.03
Development of meaningful implementation of *QR-codes*	2	2.06
Development of meaningful implementation of *software for coding*	3	3.09
Development of meaningful implementation of *educational games*	2	2.06
Development of meaningful implementation of *digital stories*	2	2.06
Development of meaningful implementation of *specific and general software* for representing particular phenomena and *peer assessment*	1	1.03
Use of *ICT in support of monitoring and development of project work*	1	1.03
Development of meaningful implementation of *specific and general software* for representing particular phenomena	2	2.06

Most frequently implemented activities on the *modification level* were the use of mobile applications for capturing, presenting and analysing experimental data (f_a(%) = 4.12, f_a = 4), as well as evaluation of various tools for preparation of concept maps (f_a(%) = 4.12, f_a = 4). The highest proportion of implemented activities on the *redefinition level* was the implementation of software for coding (f_a(%) = 3.09, f_a = 3). There are also several other activities on different levels of the SAMR model that occurred with lower frequencies.

CONCLUSIONS

This study set out to examine if and how ICT helps students to develop the technological, pedagogical and subject matter knowledge and skills needed to effectively use ICT in their future practice. With regard to the SAMR model, a significant shift to higher-order thinking skills was detected. The implementation of theory-driven ICT practice can transform student learning from a focus on the teacher to student-centred learning. The ICT used in support of the transformational level of the SAMR model can drive the construction of knowledge, enhance and enrich learning by engaging students in a better learning experience.

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