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Digital Transformation of Education and Learning - Past, Present and Future

IFIP TC 3 Open Conference on Computers in Education, OCCE 2021
Tampere, Finland, August 17–20, 2021
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Preface

This volume contains selected papers from the Open Conference on Computers in Education (OCCE 2021), organized by Working Group (WG) 3.4 of the IFIP Technical Committee 3: Education (TC3) and supported by its other working groups. The conference was run as a hybrid conference, and this event pioneered this form of practice for IFIP and TC3. The online facilities were all run from the host organization, and the onsite element was held in Tampere, Finland, from August 17–20, 2021, hosted and supported by the University of Tampere. The conference was open to researchers, policy makers, educators, and practitioners worldwide. The conference title, which was also selected as the book title, Digital Transformation of Education and Learning – Past, Present and Future, reflects the ongoing commitment to (and current interests in) research and practice in learning and technology that members of TC3 and its working groups have fostered over many years, and continue to nurture today. Submissions to the conference were invited to address the following key themes:

- Digital education in schools, universities, and other educational institutions
- National policies and plans for digital competence
- Learning with digital technologies
- Learning about digital technologies and computing

Altogether, 42 submissions of full and short papers, symposia, and system presentations were received and reviewed by an International Program Committee and additional reviewers in a double-blind peer review process. Among these submissions were 30 full and short papers, from which 24 were accepted for publication in the volume at hand. The overall acceptance rate was 80%. Each of these papers was reviewed by at least three reviewers. The papers in this book arise from contributions from (in alphabetical order) Australia, Austria, the Czech Republic, Denmark, Estonia, Finland, Germany, Ghana, India, Italy, Japan, Latvia, Lithuania, Portugal, Serbia, Slovakia, Spain, Sweden, and the UK, which reflects the conference's success in bringing together and networking experts from many countries worldwide.

The book is structured into four topical sections. There are nine papers in section 1 (Digital education across educational institutions). These cover aspects of teacher education, primary and secondary education, and then further and higher education. They are ordered in that sequence and offer new findings relating to the conference theme of "Digital Transformation of Education and Learning - Past, Present and Future". The first paper by Borukhovich-Weis et al. presents a model of digitalization-related competencies for teacher education, developed by a working group on digitalization in teacher education (WG DidL) at the University of Duisburg-Essen. Next, Černochová and Selcuk present an interesting investigation into primary education student teachers' perceptions of computational thinking using Bebras tasks. Kalaš and Horvathova then present the latest developments in their Emil school coding project and identify a set of related operations that primary pupils should learn in any particular year. Following this, the paper by Williams and Mead outlines a creative approach to the teaching of Python in secondary schools, giving worked examples of coding practice. The next two papers look at social disadvantage and inclusion. Saito contends that educational support to develop socially disadvantaged young people's digital skills and competencies has a positive impact on digital citizenship, while Cranmer and Lewin report on early findings from a research project carried out in North West England that identifies challenges in relation to the development and implementation of inclusive digital pedagogies. Batur and Brinda's paper follows, which reports on a study about students' difficulties and misconceptions in introductory programming, in the context of game design, while Corinna Mößlacher et al. look at ways to understand, and to encourage, school students' interest in computer science, through workshops and contests. A final paper on practical teaching projects, using Python, follows, in which Weigend outlines some starter projects in Python programming classes at university level.

There are seven papers in section 2 (National policies and plans for digital competence). These are also ordered and report on new insights relating to past, present, and future policy and practice in computing and digital competence in a number of different countries, reflecting the wide international scope of the book. Tatnall begins by presenting a history of the development of computing in Australia over the past fifty years. The next paper by Niemelä et al. summarizes the current situation regarding the introduction of computational thinking concepts and competencies into compulsory education in two Nordic and two Baltic countries. Following this, Fluck and Girgla provide an Australian perspective on the changing computing curricula in eight states and territories, while Kakeshita et al. from the Information Processing Society of Japan (IPSJ) present a report on their curriculum standards strategy, from the standpoint of both the academic and professional communities of computing in Japan. Castro et al. next present an analysis of contemporary, structured, and connected pedagogical approaches to the teaching of digital proficiency/fluency in 21st-century digital literacy. Following this paper, Akayuure describes Vclass, an online project for mathematics delivery at a university in Ghana, assessing the strengths and weaknesses, and ultimately validating it as a means to enhance future students' learning. Finally, Chetti et al. outline the development of digital technology to advance the teaching of smart agriculture in India.

There are five papers in section 3 (Learning with digital technologies). Initially, Andresen looks at vocational education in Denmark during school shutdown, focussing on emergency remote teaching and its implications. Then Aoki et al. analyze practical examples of a real-time online class on 'agriculture in space', using the collaborative learning tool "Digital Diamond Mandala Matrix". Opel and Netzer next describe AsTRA, a project to develop a comprehensive system to acknowledge the prior knowledge of computer science students. One of the goals is to promote permeability between vocational and higher education in computer science. Following this paper, Rötkönen et al. report on a trial of a tele-immersive platform (TIP) with elementary school 6th grade learners (12–13-year-olds) working on an environmental study lesson. They show that the 3D TIP technology has the critical potential to overcome psychological strains due to physical distance in online education. Finally, Pasterk et al. report on DigiFit4All, a project to develop a platform for POOCs (Personalized Open

Online Courses), including open teaching and learning resources, for both pre-higher and higher education.

There are three papers in the last section, section 4 (Management issues). These offer views on educational management, including a history of the significant role of IFIP TC3. Kadijevich et al. provide results of an initial study of what kinds of e-assessment feedback is important to students at university level, with suggestions for further research. Vartiainen suggests new understandings for management on how organizations may learn and fare under uncertainty, volatility, and transitioning to digital collaboration. Finally, Osorio and Banzato analyze the contribution of IFIP TC3 WG 3.7 to the development of the field of 'Information Technology in Educational Management'.

We are pleased to offer leading-edge work through this choice of papers that we hope will be of interest to further inspire your own work.

January 2022

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An Integrated Model of Digitalisation-Related Competencies in Teacher Education

Swantje Borukhovich-Weis(✉), Torsten Brinda, Veronika Burovikhina, Michael Beißwenger, Björn Bulizek, Katharina Cyra, Inga Gryl, David Tobinski, and Mike Barkmin

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Abstract. This paper presents a model of digitalisation-related competencies for teacher education, developed by a working group on digitalisation in teacher education (WG DidL) at the University of Duisburg-Essen. Currently, there are various models available that outline the competencies teachers should develop for being equipped to work in a digital world. These approaches often mention various, widely applicable digitalisation-related competences that teachers are meant to acquire, or they are based on a limited or only implicit understanding of digitalisation. The aim of the presented model is to contribute to the discussion of how to best integrate existing models. It is based on an integrated understanding of digitalisation-related competencies that encompass teaching and learning with digital media, as well as learning about digitalisation as a subject matter in its own right. At the center of the model are generally formulated competency goals for teaching and learning, for professional engagement, and for reflective, critical-constructive teaching practice. The potential for achieving these goals is then illustrated by means of interdisciplinary and/or subject-specific examples. In this way, the model can also be applied to specific subject areas and to their teaching methodologies.

Keywords: Digitalisation-related competencies · Teacher education · Frameworks of digital competence · Reference models

1 Introduction: Background and Objectives

In order to systematically promote the implementation of digitalisation-related[1] competencies[2] in teacher education programmes at the University of Duisburg-Essen (UDE), there are numerous initiatives at the university, faculty, and institute levels. The working

[1] "Digital competencies" is the standard term used in most publications. Since competencies describe abilities and skills, which are not digital per se, the authors use "digitalisation-related competencies" instead.

[2] Competencies refer to the cognitive abilities and skills that individuals can learn in order to solve problems, as well as to the associated motivational, volitional, and social readiness to use such solutions successfully and responsibly in various situations [1].

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group on digitalisation in teacher education (WG DidL)[3] supports these initiatives and at the same time develops them further for teacher education courses and for interdisciplinary cooperation between all subject methodologies at the UDE. The WG was initiated in 2017 with the participation of representatives of several school types (primary, lower and upper secondary), subjects (Computer Science, German and *Sachunterricht*[4]), Educational Sciences, and the Center for Teacher Education (ZLB). The WG works in close cooperation with representatives of other school subjects and Educational Sciences, for example through Think Tanks. The aim of the WG is to prepare student teachers adequately for their future careers by fostering their media methodology, digitalisation and computer science-related competencies across all subjects and school types and implementing them in their respective curricula. As a first step, the WG developed an Integrated Model of Digitalisation-Related Competencies for Teacher Education (hereinafter referred to as the Integrated Model). This paper is based on the German publication of the model [2] and aims at making the ideas and concepts available to a wider audience and thereby to contribute to a larger international discussion.

Currently, in Germany, there are various models and descriptive matrixes available that outline the vision for the development of digitalisation-related competencies among teachers. An analysis of existing models has led to the identification of specific focus areas and, as a result, to the need to work on further developments with regard to an integrated model:

(1) Existing models for describing digitalisation-related competencies of teachers address various aspects:

a. The much-cited Technological Pedagogical Content Knowledge (TPACK) Model [3], for example, emphasises the need for teachers to acquire and appropriately link subject-specific competencies for their respective subjects (content), pedagogical competencies, and technological or digitalisation-related competencies in order to teach in an environment shaped by technology or digitalisation.
b. The Digital Competence Framework for Educators (DigCompEdu) [4] is a European framework model for describing digitalisation-related competencies of teachers. It refers to the Digital Competence Framework for Citizens (DigComp) [5], which defines general digitalisation-related competencies of citizens. The DigCompEdu [4] as well as the German framework for North Rhine-Westphalia (NRW) called "Teachers in the Digitalized World – Orientational Framework for Teacher Education and Teacher Training in North Rhine-Westphalia"[5] [6], focus more specifically on teaching in an environment characterised by digital media as well as on the professional commitment in this regard (own professional development, school development, etc.).

[3] For more information about the working group, see http://udue.de/didlag.

[4] *Sachunterricht* (Primary Social and Physical Science) is s subject taught in primary school that combines social science and natural (physical) science education.

[5] Hereafter abbreviated as Orientational Framework NRW. Given the federal structure in Germany, the Orientational Framework NRW [6] forms a relevant basis in the German state North Rhine-Westphalia.

A model specifically tailored to the requirements of teacher education should integrate the aforementioned aspects in a suitable manner, and at the same time establish explicit, exemplary links to the content of the various subjects and their competency requirements, as well as outline associated classroom practices, pedagogies and appropriate teaching approaches. The authors consider this to be indispensable for the presentation of the subject-specific aspects of digitalisation-related competencies in teacher education programmes. They also view this to be necessary for the coordination between the different subject areas, for implementing these competencies in the respective curricula, and for communicating them within the framework of the subject-specific content and subject teaching methodology areas of teacher education programmes.

(2) Existing models for describing digitalisation-related competencies of teachers are often based on a limited or implicit understanding of these competencies: Some of the existing models, such as DigComp [5] and the German *KMK* strategy called "Educational in the Digital World" [7][6], outline digitalisation-related competencies of learners and put a special emphasis on teaching and learning with digital media. These models neglect to address digitalisation as a subject matter in its own right: analysis, design, reflection on technological and media structures and digital systems as well as their socio-cultural impact. When specifying the digitalisation-related competencies to be acquired by teachers, reference is made to the competencies to be acquired by learners. DigCompEdu [4], for example, refers to DigComp [5]. In some cases, for example, in the Orientational Framework NRW [6], the relevant competencies are not specified in any detail. This means that – as with the learner-related competencies – the understanding of digitalisation-related competencies has a one-sided emphasis, or it is not clear which aspects of digitalisation are to be used as a basis for acquiring teaching-related or other professional competencies.

The Integrated Model presented in this paper therefore integrates selected aspects of various models and descriptive matrixes into one model (see Sects. 2, 3, 4) and is explicitly based on an integrated understanding of digitalisation-related competencies.

The models considered were integrated in terms of their structural elements and explicit competency goals. In Sect. 2 the structural elements of the existing models under consideration for the integration are specified; in Sect. 3 their integration and the resulting structural model are described. Section 4 presents the result of the integration of the competency goals, which also includes their implementation and instantiation in practice from a transdisciplinary, interdisciplinary and subject-specific perspective. Section 5 gives an insight into the implementation of the model in university teacher training at the UDE.

[6] The competency descriptions contained in the KMK strategy [7] are based on the ones defined in the DigComp [5]. KMK stands for *Kultusministerkonferenz*. It is the "Standing Conference of the Ministers of Education and Cultural Affairs". The KMK strategy [7] serves as a reference framework for the development of national concepts for teacher education in various states in Germany.

2 Theoretical Basis of the Integrated Model

The core concern of the model is to bring together existing models and related discourses into an integrated model. The components of the integration are explained in the next section.

The Revised TPACK Model [8] was chosen as the structural basis, which is a further development of the original TPACK Model [3]. It describes content, pedagogy and technology as overlapping core knowledge areas for teaching in a technology-driven environment. Relevant knowledge categories for teachers are derived from the respective intersections. In the Revised TPACK Model [8] the knowledge that learners bring into the classroom is also specified, as well as the context of classroom practice and teaching methods, which, although already identified as relevant in TPACK [3], is now more nuanced (interpersonal/intrapersonal, cultural/institutional as well as physical/technological contexts are specified).

The aim of the Integrated Model is not to re-describe content-specific or teaching methodology knowledge as applicable to teacher education without a closer reference to digitalisation, because these areas of knowledge can already be found in the original TPACK Model [3]. To see how these are implemented, reference is made, for example, to the common requirements of the federal states for the subject-specific and educational requirements in teacher education programmes [9, 10].

Since the concern of the Integrated Model is to specify digitalisation-related competencies of teachers, some basic decisions are outlined below:

1. The area of technological knowledge, including its internal structuring, is taken as a basis from the TPACK Model [3], since digitalisation is assigned to this area. Due to the intersections of the technological knowledge domain with the content knowledge and the pedagogical knowledge domains in the original TPACK Model [3], the following four subdomains of teachers' technological knowledge can be identified, all of which are relevant for a model of digitalisation-related competency of teachers:

   a. Technological Knowledge, (TK) in the TPACK Model [3],
   b. Technological Content Knowledge (TCK),
   c. Technological Pedagogical Knowledge (TPK),
   d. Technological Pedagogical Content Knowledge (TPACK).
2. The knowledge areas in the TPACK Model [3] are interpreted as competency areas by the authors following the current competency orientation. The re-interpretation of the knowledge areas as competency areas is done on the basis of the TPACK structural model. The authors do not want to equate competencies with knowledge. Rather, this re-interpretation implies the transfer of knowledge elements into matching competency goals.
3. Since this article is about teachers' digitalisation-related and not technological competencies, the above-mentioned subdivision of technological knowledge in the TPACK Model [3] into sub-areas (see point 1.) including the re-interpretation of knowledge areas as competency areas (see point 2.) is taken as a basis. However, as a further step, the term "technological" is replaced with "digitalisation-related". This is in no way intended to imply that these terms should be used synonymously, only that all of the knowledge or – as interpreted here as – competency areas

defined by the TPACK Model [3] can be applied analogously to the digitalisation discussion. This idea is inspired by the DPaCK Model [11] (Fig. 1).

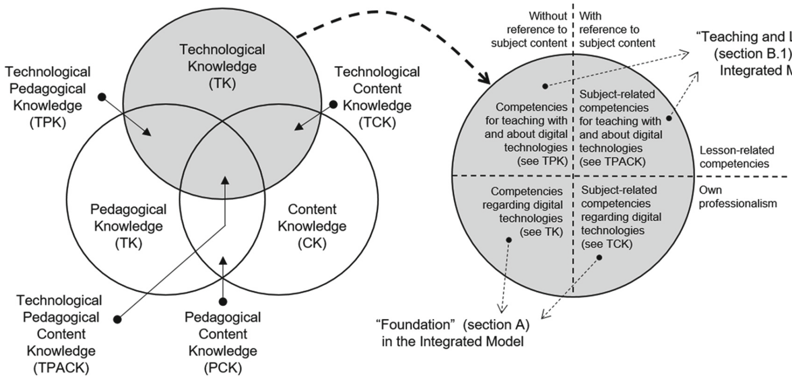

Fig. 1. Excerpt from the development of the integrated model of digitalisation-related competencies for teacher education (own representation[7] including [3])

4. Since the context categories defined in the Revised TPACK Model [8] can also be applied analogously to the digitalisation discussion, they are included in the integrated model

In addition, the Integrated Model uses relevant components from other models already mentioned (see Sect. 1):

5. DigCompEdu [4], the *KMK* strategy [7] as well as the Orientational Framework NRW [5] essentially specify teaching and learning with digital media in a subject area and beyond (included in the TPACK Model [3] as TPK and TPACK, see above). They are reified for these areas in the Integrated Model. However, an integrated understanding of digitalisation-related competencies requires an expansion of this competency area to include teaching about digitalisation as a subject (see Fig. 2, subsection B.1).
6. Furthermore, both the DigCompEdu [4] and the Orientational Framework NRW [6] describe the professional engagement of teachers with regard to digitalisation, e.g. in the areas of school development, cooperation, or professional development. This aspect is integrated as a separate area of competency (see Fig. 2, subsection B.2).
7. In order to reify the digitalisation-related basis for teaching processes and professional engagement, the Frankfurt Triangle on "Education in the Digitally Networked World" [12] is used. This model integrates perspectives from information technology, computer science education, media studies and media education. It differentiates between technological and media structures and functions, social and cultural impacts, and interaction (user options, social practices, identity construction), each of which is to be developed through analysis, reflection, and design (see Fig. 2, competency are A). The Frankfurt Triangle [12] is interpreted here as a

[7] This is a translation of a figure used in the German paper, see [2], p. 47.

meta-model over various existing models with the intention of integrating the competencies and concepts of, for example, computer science education (e.g. [13]) contained in the *KMK* strategy [7]. In this respect, it is considered by the authors to be suitable for addressing the need for further development identified in Sect. 1. By leaning on this model, the authors intent to stress that digitalisation-related teaching and learning practices must focus on both the use of digital technologies as a medium and digitalisation as a subject of instruction. The same applies to professional engagement, such as school development or one's own continuing education, which must also take both aspects into account.

3 Structure and Components of the Integrated Model

The Integrated Model describes basic prerequisites as well as institutional and instructional aspects of teachers' digitalisation-related competencies. The metaphor of a house was used for the presentation of the model in order to express, on the one hand, that all considerations of digitalisation-related teaching and learning (B.1) and professional engagement (B.2) of teachers must be based on one common foundation (an integrated understanding of digitalisation (A)). On the other hand, the metaphor is meant to illustrate that any critical-constructive reflection (C) on the overall process is to be placed over and above the aforementioned components, like a roof would be placed over a house. The inner core of the house is represented by the promotion of subject-specific and digitalisation-related competencies of learners – all surrounding aspects are aligned with these (see Fig. 2).

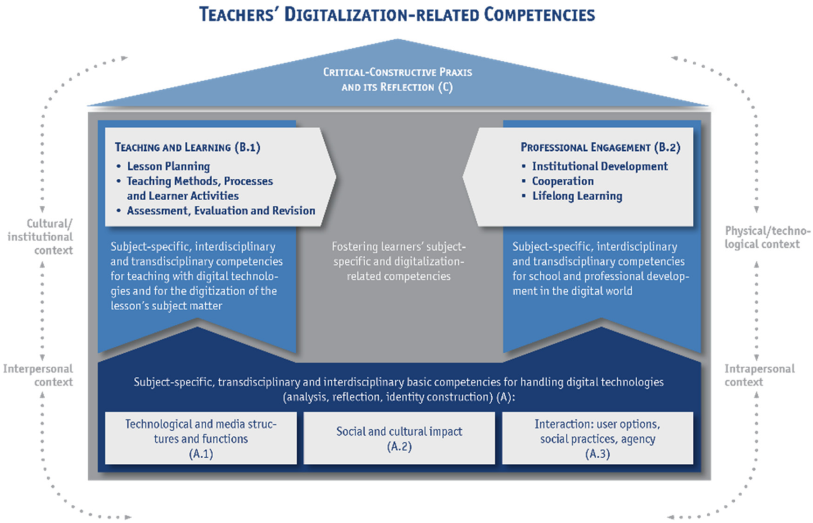

Fig. 2. Integrated Model of Digitalisation-Related Competencies for Teacher Education (own representation[8] including elements from [3, 4, 8, 12])

[8] This is a translation of the German model, see [2], p. 49.

The foundation of the house, **competency area (A)**, comprises the knowledge areas TK and TCK of the Revised TPACK Model [8] (see above). The interdisciplinary and transdisciplinary basic competencies are specified in subsections A.1, A.2 and A.3 of the Frankfurt Triangle [12]. **Subsection A.1** combines information technology and media structures and functions and thus focuses on a fundamental understanding of digital technologies and specific digital artifacts as well as the ability to participate in shaping them. **Subsection A.2** focuses on how objects of the digitalised world interact with and impact social and cultural aspects (and vice versa) and thus addresses diverse phenomena and change processes that occur in connection with digitalisation. Finally, **subsection A.3** focuses on aspects of the functional application of digital systems and media, their integration into social practices (such as teaching processes), and related aspects of identity formation. According to the subsections A1, A2 and A3 of the model, teachers and other professionals have digitalisation-related competency when they are able to analyse, reflect on, and to a certain extent help create or shape objects or phenomena of the digitalised world (e.g., data privacy, social media, virtual labs, smart home systems, self-driving vehicles) or when they are able to reconstruct them as relevant in school settings. Since the aforementioned explanations are closely connected with related subject-specific aspects (knowledge area TCK in the TPACK Model [3]), the areas TK and TCK have been combined here to form a common foundation (A).

Competency area B is subdivided into **Teaching and Learning (B.1)** and **Professional Engagement (B.2).** Competency area B is based on the DigCompEdu [4]. Since within teacher education the DigCompEdu [4] forms the counterpart of the DigComp [5], the authors consider it appropriate to lean on this model. In the DigCompEdu [4], the area of teaching and learning is divided into several separate subareas of competency: the corresponding areas are referred to as digital resources, evaluation, learner orientation, and the fostering of learners' digital competencies. In the model presented here, redundancies were identified, removed, and related competency goals combined. In the process, greater emphasis was placed on digitalisation-related subject-specific teaching and learning.

Subsection B.1 specifies the areas TPK and TPACK in the Revised-TPACK-Model [8]. Included here are competencies that relate to teaching with and about digital technologies in the respective subjects (TPACK). In addition, related interdisciplinary and transdisciplinary competencies (TPK) are also included. The area TPK includes transdisciplinary media and computer technology education aspects, for example when subject-integrated teaching and learning questions are addressed, such as algorithms or data processing, according to the *KMK* strategy [7] or the Media Competence Framework NRW [14]. In accordance with the understanding of digitalisation outlined in area A, area B.1 explicitly integrates teaching and learning with digital media and establishes the examination of digitalisation as a subject of instruction.

Subsection B.2, which includes aspects of institutional development, cooperation with colleagues and persons beyond school, and one's own lifelong learning, is outlined in the DigCompEdu [4] and in the NRW Orientational Framework [6]. In the Revised TPACK Model [8], this area is specified only in the surrounding context, which focuses on framework conditions for digitalisation-related teacher practice. Due to the practical relevance of such a framework, the context from the Revised TPACK Model [8] was included in the Integrated Model.

The institutional and cultural context as well as the network of actors involved in the process of teaching and learning (interpersonal context) influence teachers' practice. However, this scope of influence is not to be regarded as fundamentally unchangeable. Therefore, the competency areas of development (such as institutional development or collaboration) are specified. This also applies to the intrapersonal context, which includes teachers' own digitalisation-related attitudes, beliefs and competencies, which should be continuously developed through ongoing training. The physical/technological context, which refers to the systems and types of equipment available for teaching, can also be improved and adapted through appropriate media pedagogical and IT competencies, with the responsible persons ensuring that such equipment is improved and adapted in appropriate ways for the respective schools. As such, the various context categories describe relevant framework conditions for digitalisation-related teacher practice. The subsection B.2 focuses on the development of teachers' skills within these context categories as well as on their ability to co-shape them.

In **competency area C** (in the overarching roof of the model), practice is particularly emphasised once again: Within the framework of critical-constructive practice, the view should be directed not only to the overall system, which means in particular teaching-related and other professional practice of teachers at the respective school and its environment as well as the network of actors working in it. Personal involvement in and commitment to the overall system should be emphasised as well. Due to the importance of reflexivity (e.g. [15, 16]), the roof of the model expresses those competency goals that are aimed at reflection and the readiness to appreciate digitalisation for teaching and learning, school development, and one's own professionalisation.

Competency areas B and **C** are explained in detail in Sect. 4. For **competency area A**, it was decided not to specify it further here. Instead, the authors refer to the Frankfurt Triangle [12] as an interdisciplinary coordination basis. Since the Frankfurt Triangle [12] as a meta-model aims to encompass aspects of teaching and learning with and via digital technology as well as ITC education for all, reference is made to existing models for more detail, such as the *KMK* strategy [7], the NRW Media Competency Framework [14] and models of Computer Science education for all (e.g. [13]).

4 The Competency Areas and Competency Goals in Detail

The **competency areas B** and **C**, which form **the core of the Integrated Model**, are specified in the form of generally formulated competency goals. The basis for the specification of these general competency goals was an analysis of goals stipulated in already published models for education in the digitalised world, with an explicit focus on teachers' competencies: DigCompEdu [4], Orientational Framework NRW [6], the position paper "Fachliche Bildung in der digitalen Welt" [Professional education in the digital world] [17]. In addition, the *KMK* strategy [7] was used as a reference point for defining the competencies to be developed by learners that teachers, in turn, must have at a minimum. The considerations underlying the structure of the Integrated Model outlined above (see Sects. 2 and 3) thus formed a parallel, closely associated step for defining competency goals, the result of which is exemplified by some extracts from the appendix of the workshop paper [2], as shown below (see Fig. 3).

The final formulation in the Integrated Model is based on the work done by the WG DidL on various preliminary models (e.g. [18]) as well as on feedback that the WG received in exchanges with colleagues representing various other subjects and disciplines at the UDE.

The **general competency goals** are differentiated on a case-by-case basis from an interdisciplinary, transdisciplinary and/or subject-specific perspective.[9] The **interdisciplinary and transdisciplinary formulations** are based on Educational Science (especially Media Education) and, in part, on Computer Science, while the **subject-specific formulations** (initially) cover the subjects Computer Science, German and *Sachunterricht* (the three subjects represented in the WG DidL) in the German version of the model [2]; the planning of expansion through the inclusion of other subject methodologies is under way.

The formulations are not to be understood as subordinate competency goals. They are rather examples that illustrate how the general competency goals can be interpreted from a transdisciplinary, interdisciplinary, and/or subject-specific perspective. Figure 3 shows how the three competency areas, namely **Teaching and Learning (B.1)**, **Professional Engagement (B.2)** and **Critical-Constructive Praxis and its Reflection (C)**, could be operationalised from a transdisciplinary, interdisciplinary and/or subject-specific perspective.

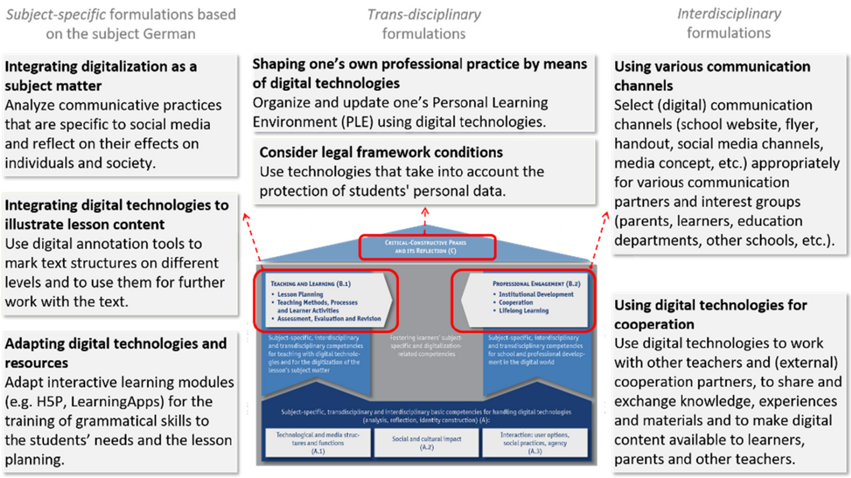

Fig. 3. Examples of how the Integrated Model could be operationalised in selected competency areas (own representation including elements from [2–4, 8, 12])

[9] Subject-specific formulations refer to observable and definable characteristics of teaching and learning in a specific subject. Interdisciplinary formulations refer analogously to a group of subjects or to teaching and learning in all subjects. Trans-disciplinary formulations go beyond teaching and refer, for example, to school development, communication or exchange with colleagues or parents, and the development of one's own digitalisation-related competencies.

The transdisciplinary, interdisciplinary and/or subject-specific formulations represent a distinction from, and at the same time a further development of the models and description matrixes mentioned in Sect. 1. The group of authors sees this as an important building block for the implementation of the fostering of digitalisation-related competencies in teacher education, as the examples serve as a guide for the practical implementation of the listed competency goals. In addition, this takes into account the fact that digitalisation-related teaching and learning should, above all, be formulated from a subject-specific perspective [17]. The examples are to be read on a case-by-case basis either as suggestions for possible implementation in university teacher training, in the classroom or as formulation sketches for the competencies to be taught.

5 Implementation and Conclusion

In this paper existing models and descriptive frameworks of teachers' digitalisation-related competencies were analysed. By focusing on specific parts of these approaches, the need for further development with regard to a model specifically tailored to the requirements of teacher education was identified. On this basis, an Integrated Model of digitalisation-related competencies for teacher education was developed.

The model can be used as a basis for research projects and teacher education. At the UDE, the model served as framework for an "Interdisciplinary Lecture on 'Education in the Digital World'". The lecture was designed and organised by the WG DidL for all teacher students at the UDE and piloted in summer 2021. The lecture aims to foster students' basic digitalisation-related competencies. Based on the proposed Integrated Model, members of the WG, representatives of Educational Sciences and representatives of various school subjects (e.g. physics, language studies, physical education) at the UDE presented trans-disciplinary or subject-specific and practice-oriented examples for digitalisation-related teaching and learning in the classroom. All contributions were aligned with the Integrated Model and represented different parts of the "house". The model is also used as a theoretical basis for several research projects, such as an online-survey on subject-specific digitalisation-related competencies among teacher students in the subject *Sachunterricht* at the UDE. The results of the survey are used to better adapt subject-specific teacher training to the requirements of the students. Furthermore, the model forms the structural basis for a good practice pool, that is currently being planned by the WG. The pool opens up opportunities for exchange among teachers at the UDE and is intended to provide impulses for the design of 'good teaching' in the field of teacher training.

In conclusion, the model synthesises existing models and is intended to contribute towards the discussion about the definition and curricular anchoring of digitalisation-related competency goals.

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Primary Education Student Teachers' Perceptions of Computational Thinking Through Bebras Tasks

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Abstract. This paper describes an investigation of primary education student teachers' perceptions of computational thinking (CT) who participated in a course 'Digital Technologies in Primary Education', and explores what these students consider difficult when developing primary school pupils' CT. In the academic year 2021/22, a revised curriculum will be introduced into Czech primary school education. Instead of 'ICT', 'Informatics' is to be introduced into the curriculum as a new subject at all school levels. Pupils' digital literacy will be formed and developed across all subjects, so all faculties of education in the Czech Republic have paid great attention to the development of primary education student teachers, to prepare them for the planned changes in school practice. Using qualitative methods, the study findings of 66 primary education student teachers (who analysed the Bebras contest for primary school pupils) were that (1) for better understanding of CT, student teachers are required to have sufficient Informatics' knowledge to be able to think computationally, (2) student teachers reported CT is close to mathematical thinking, but these two concepts are not the same, and (3) CT development in primary education requires logical thinking, reading literacy and counting abilities.

Keywords: Primary school student teacher · Computational thinking · Informatics in education · Bebras contest

1 Introduction

Since 2005, the Czech Republic's curriculum for primary and secondary school education has included 'ICT' as a compulsory subject, intending to develop pupils' ICT skills using a computer, working with basic software applications, and searching for information on the Internet. Until now, in most schools, the teaching of 'ICT' is still governed by the curricular document. Many Czech schools have, however, realised the need to prepare pupils for more advanced IT skills, and have thus included topics in informatics (programming, robotics, etc.) into 'ICT'. Such schools understand that the future of society will depend heavily on digitisation and artificial intelligence applications in most areas of the economy, industry, services, health, education, and citizenship. Therefore, for these developments, the young generation can no longer be educated according to the 2007 curriculum.

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Under the Government's Digital Education Strategy [12], the Ministry of Education, Youth and Sport of the Czech Republic (MoEYS) decided to revise the curriculum content for ICT. In co-operation with the faculties of education over three years, textbooks and teaching guidelines were developed to introduce the new subject of informatics, and the development of digital literacy across all subjects at all levels of education. In January 2021, the MoEYS published a revised curricular document with two major changes: (1) improving pupils' digital literacy development at all educational stages, and (2) the subject of 'ICT' is replaced by 'Informatics' with new educational content aimed at computational thinking (CT) development. Both changes are radical and are to be put into practice in pre-school, primary and secondary schools by 2021/22, and no later than 1.9.2023 [13].

For faculties preparing teachers, the task is to prepare student teachers for these changes within undergraduate education; especially, to prepare primary education student teachers to develop pupils' CT in the 'new' subject of 'Informatics'. The key topics of this subject are (1) data, information and modelling, (2) algorithmization and programming, (3) information systems, and (4) digital technology.

At Charles University's Faculty of Education, two consecutive obligatory courses, 'Digital Technologies in Primary Education' and 'Didactics of Digital Technology', were included in the second year of the full- and part-time five-year MA study in Primary Education. The first is organised as a set of interactive lectures focused on Papert's constructionist theory, a concept of algorithmisation (searching algorithms, code pictures, the principle of recursion, etc.) and examples of how to develop CT (CSUnplugged activities, Bebras tasks, etc.). The second is organised as a set of practical exercises in robotics (LegoWeDo kit), and programming in Scratch.

This paper reports how primary education student teachers who participated in the course 'Digital Technologies in Primary Education' perceive CT through the Bebras contest tasks' analysis, and what these students identified as difficult, when developing primary school pupils' CT using Bebras tasks, is presented.

Based on the above aims the following research question was formulated:

RQ: How does the analysis of Bebras tasks contribute to better student teachers' understanding of computing and computational thinking in primary school education?

2 Literature Review

Seymour Papert originated the idea of CT when he stated that "certain uses of very powerful computational technology and computational ideas can provide children with new possibilities for learning, thinking, and growing emotionally as well as cognitively" [14, pp. 17–18]. Wing [20, p. 33] followed up on his idea when she introduced the concept of CT as an educational approach that "builds on the power and limits of computing processes, whether they are executed by a human or by machine". Wing [21] states the most important elements are abstraction (the "mental" tool of computing) and automation (using a computer, the "metal" tool of computer scientists) and that "computing is the automation of our abstractions".

Considering that CT has become a prerequisite skill of 21st century learners, Hemmendinger [6, p. 6] argued that the goal of teaching CT to students "to teach them how to think like an economist, a physicist, an artist, and to understand how to use computation to solve their problems, to create, and to discover new questions that can fruitfully be explored". On the other hand, Lu and Fletcher [9] highlighted the importance of teaching CT as in early school education with an emphasis on understanding "computational processes, and not on their manifestations in particular programming languages" and "skills for abstracting and representing information" [9, p. 24]. Wing [20] also stressed that "to reading, writing and arithmetic, we should add computational thinking to every child's analytical ability" [20, p. 33].

Developed countries, such as the USA, Italy, Slovakia, Ireland, UK and including the Czech Republic, have integrated computing in primary school education. There is an increasing need not only for teachers, but also for student teachers to be prepared to integrate CT into their classroom practices. For example, Switzerland recently introduced a national curriculum, "Lehrplan 21", mandating Computer Science Education, the new common curriculum for compulsory education in the 21 German-speaking cantons. To discover how practical the CS Education course organised for student-teachers was, Lamprou and Repenning [8] conducted a study collecting data from more than 600 students who took the course. The research showed that even though pre-service teachers can quickly learn basic programming, the question about learning CT remains open.

With regard to studies focusing on developing primary school student teachers' competence in CT, Jaipal-Jamani and Angeli [5] investigated the effect of robotics on the learning of 21 primary school student teachers' CT in a semester-long course on science education methods. Findings from that study revealed that student teachers showed increased interest and knowledge in robots, and in self-efficacy for teaching robotics. Sadik et al. [15] investigated 12 student teachers' understanding of CT when planning and implementing a fifth-grade activity focusing on CT, robotics, and coding. The findings of the study were that student teachers showed increased awareness of CT. Some misconceptions, such as defining CT as equal to algorithm design and suggesting a trial-and-error approach to computational problem-solving did, however, persist. Similarly, Chang and Peterson [2] examined 59 primary school student teachers' perceptions and CT conceptualisations in their teaching practices. In line with Sadik et al. [15], the findings of Chang and Peterson [2] were that student teachers increased their understanding of CT and teaching applications. Moreover, student teachers improved their attitudes to including CT in their course and workshops. A study by Ma et al. [10] focused on exploring student teachers' field experience in a pedagogical laboratory designed to challenge teacher candidates' beliefs of teaching and learning in the context of CT. After 12-h' training in programming activities on robotics and practice facilitating those activities with children, student teachers reflected that they increased knowledge and skills to facilitate learning CT. Another study focusing on primary school education student teachers by Kim et al. [7] investigated STEM engagement and learning and teaching via robotics. The authors suggested that robotics can be used as a technology in activities designed to enhance student teachers' STEM engagement and teaching through improved STEM attitudes.

3 The Study

In autumn 2020, primary school student teachers at the Faculty of Education attended a 12-h compulsory course, 'Digital Technologies in Primary Education', to understand CT. The course aimed to introduce student teachers to teaching Informatics in primary school education. It was designed as a set of six interactive lectures. At the end of this course, the student teachers were allowed to choose one of the following four activities (see Table 1) to complete the course:

Table 1. List of final activities for completing the course 'Digital Technologies in Primary Education'

Activity 1	Activity 2	Activity 3	Activity 4
Code.org	Bebras contest tasks (MINI category)	Informatics Textbooks for Primary Education	Hello Ruby (books)

3.1 Participants

The course was attended by 138 second year student teachers on the 5-year MA study for Primary Education (71,7% full-time and 28,3% part-time). During their study at lower or upper secondary school, they did not have a computer science (CS) or computing subject, only the 'ICT' subject (which, in schools, was unfortunately called 'Informatics'). Among them, a few students had participated in the Informatics Bebras contest while pupils at lower or upper secondary schools. Several of them, mainly the part-time student teachers, work in primary schools and teach the subject 'ICT' to children. In the course, 'Digital Technologies in Primary Education', which introduced them to the topics and requirements for the new school subject 'Informatics', they found many interesting examples and ideas for working with pupils in primary education.

The majority of student teachers 116 chose Activity 2 in which they had to analyse Bebras tasks [1] saved in the archive (https://www.ibobr.cz/test/archiv) of Bebras contest tasks (Informatický bobřík) since 2008 for pupils from the Czech Republic.

For the Bebras task analysis, the student teachers could choose any year for the MINI category, established in 2012. Some student teachers decided to analyse tasks from different years of the Bebras contest (MIX).

The study focused on n = 66 participants (female = 97,0%) who analysed the Activity 2 related to 2019 Bebras tasks. In this study, we therefore looked at the results reported for 2019. The student teachers were allowed to do the Activity 2 individually or to collaborate in groups (Table 2).

Table 2. How student teachers worked and collaborated in Activity 2 Bebras contest 2019.

Number of student teachers (Activity 2)	Working individually	Working in pairs	Working in threes
66	29 (43,9%)	34 (51,5%)	3 (4,5%)

3.2 Bebras Tasks' Analysis

The student teachers had to decide which Bebras tasks they consider are simple or difficult and the reason why. The following scheme (see Table 3) illustrates the key steps in how to complete the given task:

Table 3. Partial steps in solving Activity 2.

Step 1	Step 2	Step 3	Step 4
To choose a year of Bebras contest	To assess Bebras tasks and to decide which of them are easy/difficult	To justify the opinion as to why the Bebras task is easy/difficult	To design a teaching situation for three selected Bebras tasks as CSUnplugged activities (didactics approach, teaching aid, worksheet, etc.)

"Predicting the difficulty level of a task on the concepts of computer science or computational thinking, like in the Bebras contest, proves to be really hard" [18, p. 145]. Each year, data obtained from Bebras contest competitors are analysed to understand better why competitors are more successful in some tasks, or why in some cases they were not able to solve the task, which could help Bebras task authors to better estimate the difficulty of the tasks next time. "The actual difficulty of the Bebras tasks will only become apparent after the competition and will often differ from the expected difficulty" [16, p. 125]. Sometimes "estimating the difficulty level of a Bebras task is done merely by intuition" [17, p. 138].

Some student teachers not only assessed the difficulty for selected Bebras tasks, but also assigned these tasks to their primary school pupils and found out which tasks were difficult for them. In this manner, some of them verified their understanding or expectations.

Some tasks from the Bebras contest were presented to student teachers at the lecture of the course 'Digital Technologies in Primary Education', some student teachers started to show interest in these tasks: in some cases they even implemented Bebras tasks to teach their pupils in schools or to activities with their children at home.

3.3 Method

In the present study, data were collected through student teachers' reflective texts (n = 66) in which they assessed the Bebras tasks for the year 2019 and explained why they assumed the difficulty level of particular tasks. The researchers utilised also the information resulting from the design of the teaching process for the three selected Bebras tasks (see Step 4 in Table 3).

In the case of student teachers, it is not a matter of agreeing on the difficulties with the Bebras tasks' authors. Their view of the task level difficulty reflects student teachers' subjective feelings, which is mixed with their own experience, as they struggled with solving the task. The Bebras task analysis is a way how to teach student teachers to think about pupil's thinking computationally.

3.4 Findings

Unlike the authors of the Bebras contest tasks who use a three-level scale to assess difficulty (*easy - moderately difficult - very difficult*), student teachers used only a two-level scale: *easy – difficult*. The two-level scale was deliberately given to student teachers since these students have practically no experience with informatics tasks and teaching computing. They are not yet able to be sufficiently clear about the thinking process about the problem nor appreciate how pupils can analyse the task, or what strategy to choose to solve it. Thus, it is not appropriate for beginners to apply *a finer scale* (see Figs. 1 and 2).

In general, student teachers reported that they very much enjoyed solving the Bebras tasks. Some of them have already participated in the Bebras contest as lower secondary school pupils. Nevertheless, for many student teachers the Bebras contest was something completely new.

In some cases, student primary school teachers' opinions on the difficulty of specific Bebras tasks diverged from the Bebras task authors' views; while, in others, the vast majority of student teachers agreed with authors of Bebras tasks.

Practically all student teachers and task authors agreed that the task **"*Text editing*"** is an easy task (Fig. 3). The student's common view was based on their belief that everyone can work with a text editor, but does this also apply to primary school pupils? Student teachers' view of difficulty level of the task, **"*Magic with coins*"**, coincides with expectations of the task authors, describing it as difficult (Fig. 1).

In some tasks, student teachers' opinions on the level of difficulty of the Bebras tasks differed, so it is not entirely clear whether, in general, for most student teachers the task is difficult or easy. Among them there are opinions both that the task is difficult, and opinions that the task is simple (see Fig. 1 and 2).

a) Bebras tasks considered very difficult according to their authors:

Student teachers evaluate these following Bebras tasks differently (Fig. 1). Like the authors of Bebras, the majority of students consider the **"*Magic with coins*"** task to be an extremely difficult. Nevertheless, some tasks that authors find very difficult, student teachers considered easy. That is the case with the logic task, ***"Entrance to the swimming pool"***, and the task, ***"Shields and swords"***, (see Appendix 2, Fig. 5).

According to the authors, the difficulty of the task **"*Entrance to the swimming pool*"** lies in the fact that pupils work with logical conditions, while the student teachers saw its difficulty only in pupils′ ability to focus on reading comprehension, associating the success of solving this task mainly with reading literacy. Only very rarely did a few student teachers comment that "in this task, pupils are required to realise what exactly the rules for entering the swimming pool say (what are the conditions for entry to the swimming pool: if - then - else) and realise what conditions are fulfilled in the given case (how old is who to whom, and who can go to the swimming pool with whom)" (Student teacher 59).

The task, **"*Shields and Swords*"**, has been described by some student teachers as easy. It is enough to carefully select individual swordsmen and realise what equipment swordsmen should have at the beginning and at the end of the row. Some student teachers also reflected their views in their teaching design for working with this task with pupils in a classroom: groups of five pupils equipped the same way as in the picture (see Appendix 2, Fig. 5) and solved this task through a drama performance.

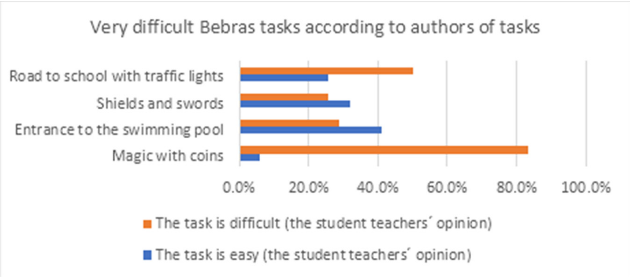

Fig. 1. Student teachers' opinions on Bebras tasks, which the authors of the Bebras contest consider very difficult.

b) Bebras tasks considered moderately difficult according to their authors:

In the case of moderately difficult tasks, the views of student teachers and authors of tasks on the task difficulty also vary (Fig. 2). Differences in the perception of difficulty were manifested mainly in the evaluation of tasks, **"*Candy vending machine*"** (see Appendix 1, Fig. 4) or **"*Cloudy weather forecast*"**.

One student teacher justified the difficulty of the task **"*Candy vending machine*"** as follows: "I think that pupils will apply a "trial and error" method. They will try to apply this method until the required number (for 44 candies) appears on the display. Pupils will not understand why this happened or how to look for a more general strategy to solve this task‟ (Student teacher 45). The student teachers' comments showed that none of them related this task to the triple system. "In my opinion, it is difficult for children to find their way in the machine itself. Working with numbers, in my opinion, is quite a challenging task for children" (Student teacher 12).

In the case of the task, **"*Cloudy weather forecast*"**, as anticipated, most student teachers described this task as easy. Problem tasks of this kind based on visual analysis are included quite a lot in the learning of primary school pupils.

A completely different type of task is **"*Little worm*"**. According to some students, the task is simple; according to others, the task is difficult (Fig. 2) "because there are several solutions to the paths and pupils have to find the shortest one. On twigs, the little worm can proceed in different directions" (Student teacher 47).

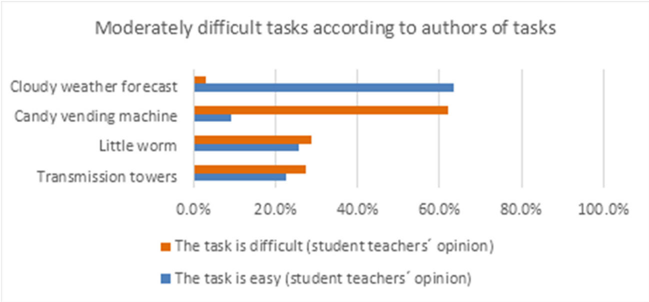

Fig. 2. Student teachers' opinions on Bebras tasks, which the authors of the Bebras contest consider moderately difficult.

c) Bebras tasks considered easy according to their authors:

For all the tasks in this group (Fig. 3), the prevailing opinion among student teachers is that these are simple tasks, corresponding to the views of the task author.

Only in case of the task, **"*Park cleaning*"** (see Appendix 3, Fig. 6), according to some student teachers the task can be difficult (Fig. 3) because the pupils will not be able to visually compare distances between objects placed in the park and "to decide which of a pair of objects is closer to the cleaning robot, and the robot then cleans it up." (Student teacher 32).

Some student teachers compared the Bebras tasks with mathematical ones used in other challenges for primary school pupils (Kangaroo, Mathematical Olympiad, etc.); they found the Bebras tasks more interesting and engaging. They appreciated the fact that the Bebras tasks usually include a picture or an interactive function, so the control of the task could be user-friendly. Student teachers also valued a theme or story of Bebras tasks –reflecting pupils' lives, interests and experiences which can be fun.

The student teachers pointed out that a significant condition for the successful solution of each task is the ability to read the assignment carefully and to concentrate on its reading with understanding. From a didactical point of view, reading and visual literacy, logical thinking and numeracy are very important for solving Bebras tasks.

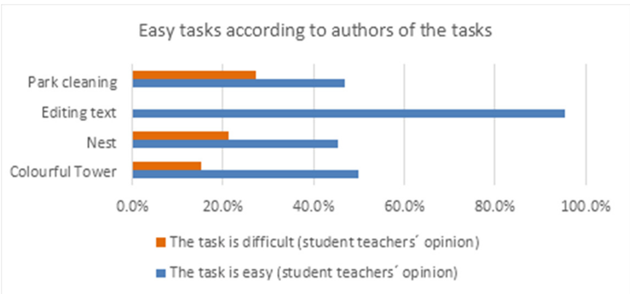

Fig. 3. Student teachers' opinions on Bebras tasks, which the authors of the Bebras contest consider easy.

The student teachers appreciated very much the opportunity they had about how a pupil could think over, and whether pupils are, indeed, capable of solving each Bebras task. They considered that to be a great contest in their initial professional development to become a primary school teacher.

As already mentioned, primary education student teachers not only assessed the difficulty of Bebras tasks, but also proposed teaching methods or approaches aimed to help pupils think about solving tasks (Step 4 in Table 3). Some student teachers created teaching aids (made of paper, wood etc.). Other teaching methods were based on pupils envisioning and enacting the whole situation as a story (something like CSUnplugged). Some examples:

Teaching Aids

Cloudy Weather Forecast: "Together with pupils, we would first number the lines in both pictures (including the weather forecast report). Then we compare step by step in which rows and columns the data from the weather report match" (Student teacher 17).

Little Worm: A teacher would explain this task to children with the use of toothpicks. "Pupils would be given a redrawn assignment on paper. The pupils' task would be to place one toothpick on each part of the branch that the little worm travels to the apple (which is bordered by a black dot for greater understanding). If the worm returns to the branch, the pupil will lay two toothpicks. Then pupils will count the toothpicks" (Student teacher 2).

Drama Teaching

Park Cleaning: "Various objects are placed around the class (garbage). One pupil will represent a robot, whose task is step-by-step to collect scattered objects according to the rules given in the Bebras task. Gradually, other pupils take on the role of a robot" (Student teacher 51).

4 Discussion and Conclusion

This study set out to explore primary education student teachers' perceptions of CT who participated in a course 'Digital Technologies in Primary Education' and explored what these students consider difficult when developing primary school pupils' CT. The finding of this study revealed that most of these student teachers completed this course successfully, analysing the required activities, especially the informatics Bebras tasks on which the study concentrated.

Based on the analysis of reflective texts of the Bebras tasks elaborated by 66 primary education student teachers, it was found that for better understanding of CT, student teachers are required to have sufficient Informatics' knowledge to be able to think computationally and to understand the informatics contexts of Bebras tasks.

During their studies at primary and secondary school, these student teachers did not have any opportunity to become introduced to computer science, as no such subject was part of the compulsory curriculum. Nor, after completing the 12-h compulsory course 'Digital Technologies in Primary Education', did the primary school student teachers show convincingly that they know what computing and computational thinking are. They did not have sufficient foreknowledge of (i) what Informatics are, (ii) how computers work, (iii) algorithms, (iv) programming, and knowledge in mathematics, but (and at the same time) they would be required to develop pupil CT.

The study's findings indicate that due to their lack of fundamental knowledge in informatics, student teachers did not differentiate greatly between CT and mathematical thinking. This conclusion concurs with Millwood et al. [11] that "mathematical concepts are clearly linked, but Computational Thinking defined as the problem solving & design to create useful solutions demands a much broader, creative and playful approach engaging children's imagination" [11, p. 8].

Informatics in primary education, including CT development, requires not only logical thinking, reading literacy and counting abilities, but also a good level of abstract thinking, which - like mathematical thinking - is still developing in primary school pupils. Teaching using puzzles, quizzes and games can support and develop understanding and learning of algorithms. Such teaching has been successful in the study of other computing disciplines [4]. Most Bebras tasks are so designed.

The study showed that primary education student teachers do not yet have an idea of what it means to think computationally. It will be necessary to focus first on this in the subject, 'Digital Technologies in Primary Education', and only then to address teaching issues of how to teach computational thinking to pupils. This finding fully corresponds to the recommendations of Yadav et al. [19], that "teacher educators need first to develop pre-service teachers' knowledge and skills on how to think computationally and then how to teach their students to think computationally. It is thus imperative for pre-service teachers to understand computational thinking in the context of the subject area which they will be teaching. This requires them to have deep understanding of their own discipline and knowledge of how computational thinking concepts relate to what students are learning in the classroom."

In primary school teacher education, it is necessary to pay great attention to the evaluation of informatics tasks for pupils, so they can "grasp" the informatics content of an assessed task. The student teachers in this study evaluated the Bebras tasks as interesting tasks (such as quizzes or games); they did not have enough insight from CS to notice what and why it may be difficult for pupils working on Beaver tasks. They assessed difficulty mainly according to their ability to solve the task. They applied a certain "automated" (stereotypical) thinking procedure for solving problematic tasks which could be a barrier to gain insight into completing the task.

For primary education student teachers to really develop CT, they need a grounding in CS, otherwise "there is a real danger that Computational Thinking becomes a label for a set of enjoyable time-filling activities with little coherence and a lack of continuity and progression" [11, p. 14]. To ensure primary school development of CT, initial teacher education cannot concentrate only on pedagogical issues of pupils' CT development but must also include informatics. We agree with Cutts, Connor and Robertson [3, p. 26] who argue that "efforts to make computer science entirely about "computational thinking" in the absence of "computers" are mistaken".

Acknowledgement. This study is a result of the research funded by the PROGRES Q17 Příprava učitele a učitelská profese v kontextu vědy a výzkumu.

Appendix 1 Candy Vending Machine

Set the candy machine to dispense 44 candies. Use red sliders to change the setting.

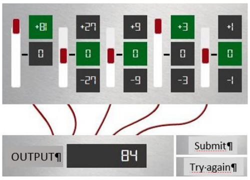

Fig. 4. Candy vending machine. (Color figure online)

Appendix 2 Shields and Swords

Drag to place masters of historical fencing (swordsmen) to apply:

- Each sword points to one of the masters (swordsmen).
- The master (swordsman) must defend himself with a shield against each sword.

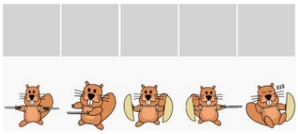

Fig. 5. Shields and swords.

Appendix 3 Park Cleaning

After the concert, a lot of garbage remained in the park and the robotic waste bin has the task of collecting it. The robot works according to the following program:

As long as there is an object on the lawn, drive to the nearest object, pick it up and load it. Which of the objects will the robot load last?

Your answers: a) , b) , c) , d) , e) I do not want to answer.

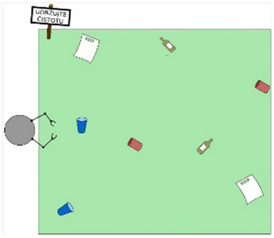

Fig. 6. Park cleaning.

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Programming Concepts in Lower Primary Years and Their Cognitive Demands

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Abstract. In our Computing with Emil project, currently in its 4th year, we are engaged in the design and research focused on productive constructionist learning of programming at the primary level, as a continuum from year to year. We are exclusively concerned with *computing for all learners* approach, being implemented by generalist primary teachers in their own classes. For similar purposes, national curricula usually list computational concepts, which pupils should learn and, in general agreement among educational experts, are considered developmentally appropriate for the primary school. However, in our work, we feel the vocabulary being normally used for this is too coarse-grained to clearly specify the learning goals, especially in the area of programming. Therefore, for each computational concept, we try to identify a set of related operations that primary pupils should learn in any particular year. In this research, we tried to verify whether our approach is comprehensible for teachers and prolific in outcomes for their pupils. We wanted to find out whether they realise that (a) different operations performed with each concept have different cognitive demands, and (b) these demands determine the arrangement of activities in an intervention. We addressed a large group of teachers who had already participated in our professional development sessions on the intervention for Year 3. We chose repetition as one of the concepts and designed six assessment tasks focused on various operations that pupils perform with it. We did not inform them of how we rank the tasks; we asked them to solve them and rank from the simplest to the most difficult, and explain their decision. We analysed the collected data by various methods, and in the paper, we discuss our findings. Teachers correctly distinguished different operations and helped us better understand challenges of projecting and assessing conceptual understanding.

Keywords: Programming in lower primary · Concepts and their cognitive demands · Generalist primary teachers' perspective

1 Introduction

In our research, we strive to better understand learning process of the primary level pupils (aged 5 or 6 to 10 or 11) in the area of computing and its programming. This arena is meagrely explored, especially if we are primarily interested in *computing for all* approach [1], i.e., in computing implemented in a regular class with all learners, possibly as a mandatory subject or integrated in mathematics. Additionally, in our case,

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we are to build the educational content such that the generalist primary teachers feel confident to teach it themselves and consider it prolific for their pupils.

In this project, we focused on the assessment of cognitive demands [2] of the programming concepts which, according to the research literature and our own experience, we consider to be developmentally appropriate for primary school. Such concepts are often only briefly listed in policy documents, curricula or research reports, as e.g., in the current English programme of study at KS2 [3]: … *use sequence, selection, and repetition in programs; work with variables and various forms of input and output.* In our approach, however (see [4] or [5]), we prefer to use more detailed vocabulary when setting educational goals and projecting learning progression for individual years in KS1 and 2. Specifically, for each concept whose understanding we want to develop, we identify operations which we consider appropriate to perform with that concept. Subsequently, in the design research process [6], we transform the operations into gradation of activities and iteratively evaluate them in our partner primary classes.

Although such design requires a long period of time and is being evaluated in numerous iterations, here we present how we additionally tried to validate whether our *concepts and related operations* strategy is productive, i.e., whether primary pupils (and teachers) are aware of the differences between individual operations related with the concepts, perceiving them as different also in terms of their cognitive demands.

2 Programming Concepts at Primary Level and Their Difficulty

Although not always used with identical meaning and scope, several curricular documents exploit the strategy of identifying programming concepts which pupils are meant to learn (see e.g. [7, 8]). Similarly, many authors in their research and development reports take comparable approaches while presenting their area of interest and formulating their research problems. The concrete lists of concepts sometimes reflect selected programming environment. Bers [9] refers to *children learning basic concepts and powerful ideas of coding* in ScratchJr as they use programming blocks spanning *concepts from simple sequencing… to control structures*, and addresses *sequencing, repeat loop, sensors, and conditional statements* when they use KIBO.

To assess development of pupils' computational thinking in Scratch, Brennan and Resnick [10] uses three key dimensions: computational concepts (namely *sequences*, *loops*, *parallelism*, *events*, *conditionals*, *operators*, and *data*), computational practices (*being incremental and iterative*, *testing and debugging*, *reusing and remixing*, and *abstracting and modularising*), and computational perspectives (*expressing*, *connecting*, and *questioning*). When Meerbaum-Salan et al. [11] investigate whether Scratch can be used to teach concepts of computer science, they studied pupils' understanding of *initialisation* (of position, direction, costume etc. up to variables), *bounded*, *conditional*, *and unbounded repeated execution*, *variables*, *conditional execution*, *message passing*, *events*, and *concurrency*.

In K-12 Computer Science Standards [12] the authors name the concepts for ages 8–11 in chapter Algorithms and Programming by stating: *Create programs that use variables to store and modify data* and *Create programs that include sequences,* *events, loops, and conditionals* (p. 10) and also provide more specific justifications plus several developmentally appropriate examples of those concepts in use.

When designing their informatics curriculum, Dagiene et al. [13] specify each concept together with one or two related operations, situating them into recommended age group. For instance, *loops without parameters* (age group 7+) are presented as *First pupils recognise repetition of patterns in programs and can shorten the program description by applying repeat-loop. Secondly pupils recognise possible repetitions in task descriptions… and design programs with loops* (p. 350). Some authors specify the need to study cognitive demands of programming, such as Blackwell [2] in his discussion about why programming is deemed difficult. In 1976, Perlman [14, 15] also suggested considering *cognitive difficulties* while developing interventions for children.

Although the researchers and content designers usually have a clear idea of a certain appropriate order of the studied programming concepts, deeper understanding and systematic research in this direction is still in its early stage. Therefore, we aim to try to verify if the strategy of identifying different operations related to each programming concept and sorting them by their different cognitive demands is productive to design structure and learning progressions in curricula.

2.1 Computing with Emil: Project Background

The reason why we consider the combination of parallel research and development to be exceptionally fruitful is that we research to ensure that we can develop competently. Moreover, we develop so that we can study corresponding learning processes. These intertwined activities signify the essence of a research strategy named design research (DR for short) [6], which we employ. At the initiation of our Computing with Emil project in 2017, we wished to not only systematically support learning in informatics through all primary years, but also equip ourselves with powerful research instruments. Exploiting them already [16], we explore one of our key design principles – distinguishing between *direct manipulation*, *direct control*, and *programming*.

At the level of content development, we strive to support programming as a continuum in all primary years. We want pupils to experience it as an opportunity to encounter powerful ideas of computing, as an instrument for their computational curiosity, a way of thinking about and solving problems from different areas. So far, we have deployed Emil for Years 3 and 4 and Robotics with Ema for Years 1 to 4. All of these interventions complement each other and support a holistic learning progression, together with the ScratchMaths interventions for Years 5 and 6 [17].

Concepts, Operations, and Tasks. In Emil Y3, we focused on the following powerful ideas of computing: *experiencing order and structure* (in data and commands), *learning to control and plan*, *coping with constraints*, *considering state and tools*, *learning to aggregate and abstract*, and *thinking about programs*. From the perspective of the programming concepts, we decided to concentrate on *sequence*, *repetition* (continued in Y4), and pre-concept of *procedure* (as a preparation for Y4). As with other interventions, in the DR process of Emil Y3, we proceeded by identifying different operations related to each concept, and implemented them in small activities that constructed the whole gradation (systematic progression) of tasks. In Emil Y3, the overall gradation consists of 150^{+} tasks. Some of them have multiple solutions, a few do not have any solution (and teachers invite pupils to explain why), while other tasks are partially ‘unclear’. In this case, the teachers suggest that the group discuss the task, complete its wording and solve it. Thus, pupils become co-designers of the activities. Discussions and collaboration in the group are the most important part of our pedagogy.

As an example, let us present how the operations related to *repetition* were identified in Emil Y3, here listed according to their increasing demands (as validated in the DR process). Here we refer to Fig. 1, which shows growing expressive power of the language along with the interface support for the way in which commands are displayed as small blue cards on the record/programming panel above Emil’s stage:

- Directly control Emil using the *basic commands*. An *external record* of the steps taken is built in parallel on the panel (see an example on Fig. 1(i)).
- Experience the limitation of the panel’s extent, which sometimes only possess 4 or 5 positions. This may affect or even preclude the solution of a problem.
- Read a given record (a simple sequence of *basic commands*) and recognise whether any command in the record is repeated more than once in a row. In Fig. 1(i) there are three such groups: two *baskets* to pick a mushroom, three *watering cans* to water a cherry tree to (1) grow, (2) bloom, and (3) ripen, and two *arrows down*.
- In direct control, discover a mechanism that any *basic command* repeated more than once in a row is automatically and immediately gathered in a *stack of commands* (see Fig. 1(ii)). This gathering is highlighted by an animation on the panel. In the example we can see three such stacks.
- Program a solution of a problem, making use of the fact that identical cards in a row are gathered in stacks. This saves positions on the panel considerably.
- When programming a solution, discover a procedure on how two consecutive *basic commands* can be merged on the panel into one ‘double card’, representing a pair of commands. Identical double cards in a row are then automatically gathered in *stacks of double cards* (see Fig. 1(iii) and (iv)).
- Build, read, analyse, explore, explain, simplify and compare different programs using *basic commands*, *stacks of basic commands* and *stacks of double commands*.
- When programming a solution, generalise the merging and stacking mechanism to three *basic commands*, which can later be changed to four (see Fig. 1(v)). Build, read, analyse, explore, explain, simplify and compare such programs.

Fig. 1. Different levels of the ways in which commands are displayed on the panel.

Our intervention for Y3 began to be implemented in primary schools in Slovakia, Czech Republic, and in smaller pilot hubs of schools in Norway and England a year before the pandemic. At that time, we also finalised the evaluation of intervention for Y4 and started running professional development (PD) sessions for teachers. Admirably, many schools continued using the interventions with their pupils in one way or another through the pandemic. The actual situation of 2020/21 school year, however, did not allow us to work directly with the pupils. Therefore, at this stage of the research, we focused our effort on the teachers, as we set out to study whether they realise the difference between varying operations which pupils perform with the same computational concept and how they characterise these operations. Therefore, we formulated our first research question as: *Are the teachers aware of different operations which pupils perform with each computational concept and how would they characterise them?* (RQ1) We decided to focus on repetition as one of the central concepts of the intervention in Y3 and designed a set of six paper-based assessment tasks. They represent six different operations and were intended to examine whether teachers are aware of the different cognitive demands of the operations. Therefore, this aspect was reflected in our second research question: *How do teachers perceive cognitive demands of different operations pupils do with the same concept?* (RQ2)

3 Method

Firstly, the participants of our research are characterised. We focused on all teachers who had already participated in our PD sessions[1] aimed at Emil Y3. This comprised (as of 30 April 2021) of 1079 teachers, 823 Slovak and 265 Czech. Out of these teachers, 302 agreed to proceed with our research assignment. As the final *volunteer sampling*, 62 teachers (21%) responded and undertook the challenge, as presented in Sect. 3.1.

[1] That is, one day session of face to face or two afternoons in the online model.

We will be referring to them as our *teacher sample*. These 62 teachers represent 49 schools, 37 Slovak and 12 Czech. More details of the same are presented in Fig. 2: in (a) it shows that 36 of the sample are primary teachers, 23 are lower secondary teachers who teach both primary and lower secondary pupils, one currently teaches lower secondary pupils only but is interested to know our intervention, and two are ‘other’. In (b), we see that 27 teachers have already used the intervention in their class(es) and 35 have worked with it only in the PD session(s). In (c), we see the breakdown of the sample with respect to when the teachers participated in the PD session, grouped into six half-years, starting by the second half-year of 2018.

In parallel, we also identified 13 Slovak and Czech expert informatics researchers[2] and educators in the academic population with the same request. We received eight responses, therefore deciding to use them as another validation of our method (see below). In this paper, we will be referring to this purposive sample as our *expert*.

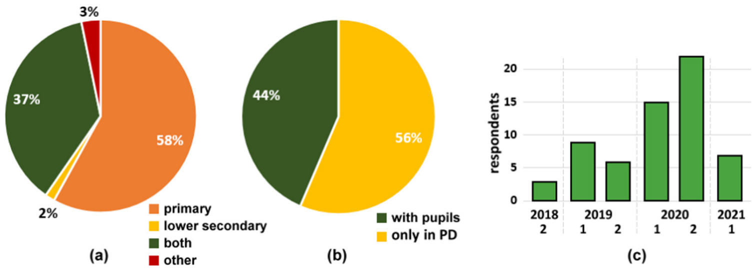

Fig. 2. Breakdown of the teacher sample.

3.1 Designing the Assessment Tasks

For this research, we designed six assessment tasks similar to activities performed by pupils (and the teachers) with repetition in Y3 intervention. Yet, the assessment tasks are dissimilar to the activities of the intervention as they are not open-ended and can be unambiguously assessed (although tasks 3 and 4 have multiple solutions). We ordered the tasks in the way corresponding to the increasing cognitive demands as implemented in the intervention. For the needs of the data analysis and the presentation of the findings, we numbered and colour-coded the data. Table 1 briefly characterises the essence of each task, while Fig. 3 illustrates one of the tasks.

[2] Familiar with our approach and our interventions.

Table 1. Cognitive characterisation of the assessment tasks focused on repetition in Y3.

Task 1		analyse a given record (program) of the single *basic commands*, recognise and mark each group of single commands repeated in the record next to each other
Task 2		read a given record of the *basic commands* and *the stacks of basic commands* and execute it; draw a resulting path of Emil through the stage
Task 3		plan a solution, i.e., program a path using *basic commands* and *stacks of basic commands* (single cards), with limited number of steps
Task 4		plan a solution, i.e., build a program that uses *basic commands* and a given 'double command', with limited number of steps
Task 5		read a given program with *stacks of cards* and *double cards* of the basic commands, and indicate the *basic command* Emil will run first, second, third etc.
Task 6		read a given program with *stacks of cards, double cards and triple cards*, and indicate the *basic command* Emil will run first, second, third etc.

3.2 Data Analysis

We randomly shuffled the set of our assessment tasks and distributed them (in the same random order) to all teachers of the volunteer sample of 302 and our purposive sample of 13 experts. We asked them to (a) solve the tasks, (b) rank them by the cognitive demands – as they perceive it – from the easiest to the most difficult one, (c) explain the reasons for ranking each task as they did, and (d) share the scans of their solutions. We obtained 70 complex responses (eight in the expert sample and 62 in the teacher sample) and analysed the data using various descriptive and analytical statistical methods, along with analyses of the explanations and the solutions. Although we applied various methods to collected rankings, we consider this research endeavour as qualitative and harness all results as a means to:

- Validate the approach of *refining granularity* of the programming concepts specifications in school informatics by identifying gradations of operations connected with each concept. Thus, we wish to learn more about how to design structure of the content and support the learning trajectory of the pupils in informatics.
- Inform our effort to better understand cognitive demands of the operations, thus improving the understanding of the programming/algorithmic thinking development at the primary stage.

To achieve this, we formulated research questions RQ1 and RQ2 (see above). As discussed in the final section of the paper, in the second period, we plan to extend this research by addressing the pupils of the teachers involved.

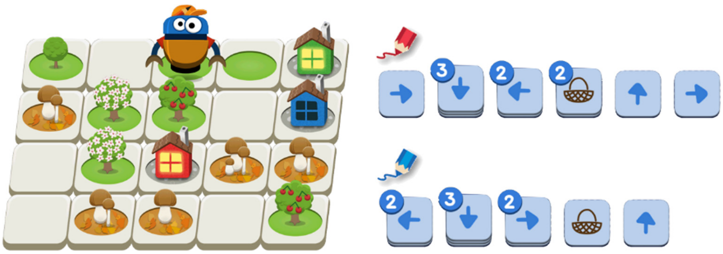

Fig. 3. Task 2, as presented to the teachers, with the following assignment: *This is Emil's stage and two records of the paths that he could take.* ***Draw both paths through the stage.***

For brevity, we present here only one method out of several which we used to analyse the collected data. Namely, we wanted to consider the degree of similarity between our understanding of the cognitive demands of the different operations' pupils in Y3 perform in the context of repetition represented as a tuple (1, 2, 3, 4, 5, 6), and collected rankings of the tasks' demands as perceived by the teachers represented as permutations of the initial tuple. To measure the ordinal association between two tuples, we used the Kendall rank correlation coefficient [18]. The value of the coefficient lies between the interval of −1 (a perfect disagreement, in this case for (6, 5, 4, 3, 2, 1)) and 1 (a perfect agreement). The correlation is high when an assessment of the perceived cognitive demands of the tasks is similar to the intended one.

Kendall's correlation coefficient, referred to as *Kendall's tau*, is calculated as the difference between the number of *concordant* and *discordant* pairs within the tuple, divided by the binomial coefficient of the tuple's length. From the CS perspective, the Kendall's tau can be easily derived[3] from the minimal number of necessary swaps between the items of a tuple when sorted by bubble sort. For example, if the perceived ranking is (2, 3, 4, 1, 6, 5), four swaps are needed to sort the tuple and the similarity between the tuple and (1, 2, 3, 4, 5, 6) is 0.467 when represented as the Kendall's tau.

4 Results

To investigate whether teachers are aware of the differences between various operations performed by the pupils with repetition in Y3, we asked them to solve our six assessment tasks and rank the task they considered the easiest to the most demanding. The resulting rankings can be analysed from two (closely related) alternative perspectives: we can review, which of our tasks was ranked by the participants as the easiest, which was ranked as the 2nd etc., while the other possible view would consider which rankings were assigned to our task 1, which rankings were assigned to our task 2 etc. Both perspectives proved to be interesting and instructive.

3 More precisely, tau = (n – 2 * m) / n, where n is the minimal number of swaps needed in the worst case and m is the minimal number of necessary swaps for this particular tuple.

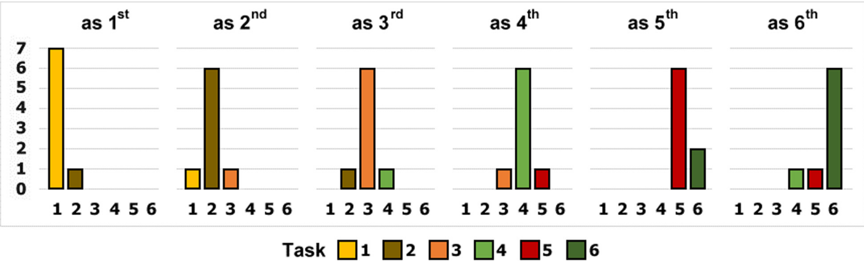

Fig. 4. Expert sample (n = 8) rankings of the tasks. (Color figure online)

In Fig. 4, the rankings of the experts are analysed (n = 8). For example, our task 1 (yellow) was assessed seven times as the simplest one and once as the 2nd. Task 2 was once assessed as the easiest, six times as the 2nd and once as the 3rd. In general, we see that experts significantly validated our understanding of the increasing cognitive demands of the different operations, although the variance in their rankings slightly increases towards more demanding tasks. As we noticed similar trend in the teacher sample, we will provide our interpretation of this in the discussion.

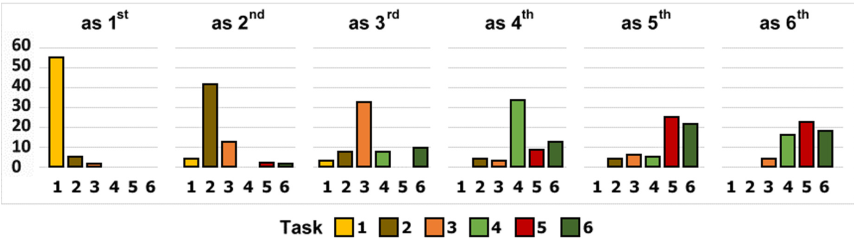

Fig. 5. Teacher sample (n = 62) rankings of the tasks. (Color figure online)

In Fig. 5, we see corresponding visualisation of the teacher sample (n = 62) rankings. In general, it shows that teachers perceive the differences between the operations related to repetition in Y3 and classify their cognitive demands in accordance with the experts and the authors. However, the variance in their rankings is significantly higher and considerably increases towards the harder tasks, with our tasks 5 and 6 being undistinguished in their cognitive demands. This is clearer when we use the alternative perspective on the rankings (see Fig. 6), showing the variability of the tasks which experts and teachers assessed as the 1st (the easiest), as the 2nd, and so on.

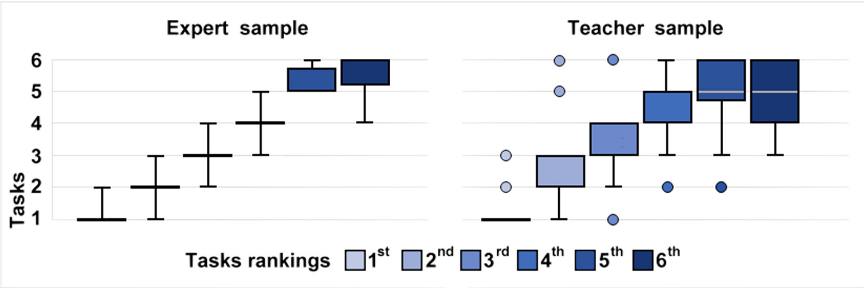

Fig. 6. Variation of the rankings in the expert and teacher samples.

Single points located *distant* from either the lower or upper quartiles (i.e., outliers) are depicted here as small circles. Note that in the expert rankings, only the last two tasks show non-zero interquartile range (Q_1, Q_2 and Q_3 being identical), with medians still being 5 in the 5th place and 6 in the 6th place. The variability in the teacher rankings is significantly higher, with the medians being 1, 2, 3, 4, 5, and 5. Clearly, while all operations are being recognised by the teachers as different, the interquartile range grows considerably from left to right and the cognitive demands of our tasks 4, 5 and 6 become blurred, especially in the last place of the rankings.

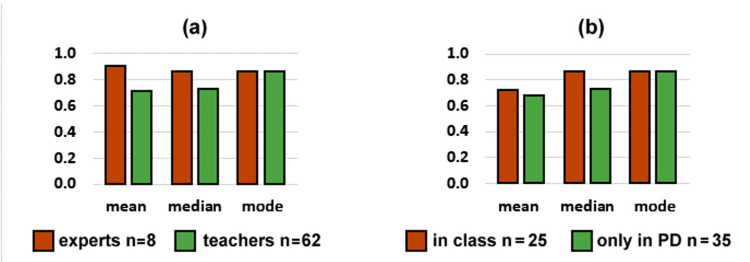

Fig. 7. Kendall's tau correlations (a) in expert and teacher samples, and (b) in the breakdown of the teacher sample into those who have used the intervention in the class and who have not yet.

To analyse the data from another perspective, we measured the ordinal association between collected rankings (cognitive demands of the tasks as perceived by the experts and by the teachers) and our implemented ranking, deriving the Kendall rank correlation coefficient (Kendall's tau) for each. Figure 7 demonstrates a few basic statistics descriptors of the results, after excluding one outlier with negative tau (based on the related textual comments). In (a) certain differences in the expert and teacher samples can be seen, most significantly in the mean and median. Diagram (b) describes the rankings of the teachers (n = 62) breakdown into those who have already used the intervention in their classes and those who have so far taken part only in the PD session. Any significant difference in those two data sets was not observed, except that the *in-class* data set has higher median and its upper 50% scores are between 1 and

0.8667, i.e., only one or less necessary bubble sort swap between the items of their rankings and our understanding of the increasing cognitive demands (1, 2, 3, 4, 5, 6).

4.1 Experts and Teachers' Justifications of Their Rankings

Another source for our research effort, interesting in the context of both RQ1 and RQ2, were the textual explanations provided by the experts and teachers, in which they justified their rankings. During the analysis, we relied on the corresponding correlation coefficients of the rankings and our initial intended ranking of the tasks' demands. The first important finding achieved in this manner is that all participants are clearly aware of the differences between operations with the same concept and can characterise them properly. Furthermore, we obtained better insight into why the variance in the rankings increases towards more demanding tasks (Table 2).

Table 2. Selected justifications of the experts' and teachers' rankings.

Experts confirming intended ranking (with Kendall's tau between 0.8667 and 1)
• (Task 1) *simple representation, simple reading of a sequence of commands*
• (Task 2) *stepping through a program with simple stacks of single basic commands*
• (Task 3) *understanding basic commands, their repetition, the rules of moving Emil*
• (Task 4) *looking for a solution which uses given double card repeatedly*
• (Task 5) *understanding what double card represents, how to step through a program*
• (Task 6) *same as 5, but containing triple cards*
Experts justifying different rankings (with Kendall's tau between 0.7333 and 0.8667)
• (Task 3 as the 4th) *programming with limited number of steps, considering alternatives*
• (Task 4 as the 6th) *programming with a given double card*
• (Task 5 as the 6th) *understanding how repetition works*
Teachers confirming intended ranking (with Kendall's tau > 0.5)
• (Task 1) *simple representation, no algorithm, only reading a sequence of simple steps*
• (Task 2) *reading a program with known notation, stepping through simple program*
• (Task 3) *programming simple steps and stacks of simple steps*
• (Task 4) *planning a solution with stacks of simple steps and double steps*
• (Task 5) *understanding the repetition of double cards*
• (Task 6) *harder than 5 because it requires reading a program with triple cards*
Teachers justifying different rankings (with Kendall's tau $\leq$ 0.5)
• (Task 3 as the 1st) *simple programming with commands gathered in stacks*
• (Task 5 as the 2nd) *simple counting the commands*
• (Task 6 as the 3rd) *understanding the order of the steps, understanding the notation*
• (Task 6 as the 4th) *understanding the order of the steps when double cards and triple cards are used in the program*
• (Task 3 as the 5th) *programming with limited number of steps, understanding the number of repetitions*
• (Task 3 as the 6th) *programming (planning a solution) is required*

5 Discussion

In this research, our aim was to investigate whether our *granularity refinement strategy* (as we put it in [19]) is productive in setting learning goals. We tried to not only better understand which concepts are developmentally appropriate for the primary stage, but to assess this adequacy in more detail, in the context of the various operations that pupils have to perform with each concept in different KS2 years.

We contacted more than 300 teachers and computing education experts, who had already attended PD session(s) on our intervention for Y3 and asked them to solve a set of six assessment tasks, ranking them from the easiest to the most difficult and comment on their choice. We gathered 62 + 8 responses and applied various statistical methods to the data obtained in this way. For instance, we studied the degree of similarity between our understanding of the cognitive demands of the different operations implemented in the tasks and participants' own rankings.

Both expert and teacher samples clearly confirmed our assessment of different cognitive demands of the operations and their proper gradation. However, especially in the teacher sample, the variance in the rankings increased towards more demanding tasks, with tasks 5 and 6 becoming almost equal in their demands. Hence, when planning or analysing the suitability of activities gradation for certain age group and expectations, at least two factors must be considered: one stems from the inherent cognitive demands of different operations pupils must perform with a concept, the other represents the pedagogy applied. Naturally, there are several ways depicting how the intervention can implement specific progression (still respecting the inherent gradation of the cognitive demands). Our pedagogy is based on the constructionist epistemology, which always starts with concrete experience and *direct control* [16] to acquire an opportunity to discover new operation (in close collaboration in the pairs and regular whole class discussions), new mechanism or new reaction, such as the one that repeats *commands* automatically gather in a *stack of commands*, Fig. 1(ii to v). Only then the gradation proceeds to *programming control* [ibid] and practising a new piece of knowledge. This, however, has the consequence that if pupils or teachers have already made a discovery, new operation or mechanism becomes known and as such 'simple': in the assessment tasks they see well known notation and its meaning they already know.

In spite of this, all experts and teachers in general agreed on our perception of growing difficulty of the operations, with tasks 1, 2, 3 always preceding 4, 5 and 6, with 4 easier than 5 and 5 easier than 6 for most of the experts. Most importantly, all experts and teachers were aware of the differences between the operations related to repetition, correctly naming and distinguishing between them.

We also noticed other interesting details, which, however, need to be followed in more detail, such as whether the rankings are influenced by the time span since attending the PD session, whether they already have real experience from the class (Fig. 7b) etc.

Acknowledgments. This work has been funded in part by VEGA Slovak Agency under project *Productive gradation of computational concepts in programming in primary school* 1/0602/20.

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"Literacy from Python"

Using Python for a Proposed Cross-curricular Teaching and Learning Model

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Abstract. This pilot case study, which outlines an introductory computer programming project, using Python, builds on the international success of the "Literacy from Scratch" teaching model [1–3]. Its aim is to contextualise the teaching of Python through a cross-curricular teaching and learning model, rather than through teaching Python elements separately. It therefore recommends the development of elementary coding skills by pupils, aged from 10 to 14 years, through the creation of very short stories or scripts, using Python strings. Each story chapter of the project further introduces worked examples of additional Python programming elements such as Turtle graphics and times-tables, within the constructionist framework of a creative writing project [4]. The project is supported by a free website for teachers. Our hope is that this creative approach to coding may encourage the enthusiastic adoption of such a cross-curricular method for teaching and learning computer coding with Python in our schools.

Keywords: Python · Scratch · Story-telling · Cross-curricular teaching and learning · Creativity · Constructionism · Contextualisation

1 Introduction

Teachers in England state schools are required to teach two computer programming languages to their students, from age 5 years. One of these languages can be a visual or "block coding" program, such as Scratch, but the other must be text-based, such as Python. In practice, the programs most commonly used in England's schools, because they are free, are Scratch, frequently for pupils aged 5 to 11 years, followed by Python for ages 11 years upwards. Some schools purchase computer programming packages because they come with prepared lesson plans, and teaching strategies. To support the development of Scratch in our UK schools, Brunel University London, and Charles University in Prague, Czech Republic, with Torino University, Italy, developed the free website, "Literacy from Scratch". Devised by Lawrence Williams (at Brunel's Education Department), and quickly shared with other teacher training teams abroad, it proved to be very popular, and an accompanying text book was subsequently commissioned, and published, by Routledge [5]. The learning model for Python, presented here, is founded on the same constructionist and psychological principles [6].

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My previous work in "Literacy from Scratch" at Brunel's partner schools in west London, resulted in pupil projects being fully completed by an entire Year 8 group (160 students, aged 12–13 years) at Bishop Ramsey School, and later by a Year 1 class (aged 5 years) and a Year 2 class (aged 6 years) at the Swaminarayan Primary School. All of the pupils involved met all the assessment criteria for the project, including story-telling, use of dialogue, animation, and simple art work for creating backgrounds and story characters. The success of this earlier project rested partly on the contextualisation of the learning of coding: secondary school pupils wanted to tell their stories, and the only way to do this was through using accurate Scratch coding, a powerful incentive to learning. At Primary school level (5 years to 11), the teachers already knew how to develop creative writing skills, and, once again, Scratch became the new means by which to deliver creative and animated narrative work. Contextualised learning, in our view, clearly helps students to make connections between the content of their studies and the context in which it is developed. Vygotsky [6] refers to this as the "gap between what is known and what is being learned". Students draw from their previous experience (in this case, of writing narratives, creating characters and dialogue) to give new meaning to what they are now learning i.e. Scratch and Python computer coding [7].

The second requirement of using a text-based computer language, however, is more difficult for UK teachers, currently still largely untrained in programming. Following the classroom success of the "Literacy from Scratch" teaching and learning project, we (the paper authors) are starting to develop "Literacy from Python", based on this earlier curriculum model. It aims to support the following elements of the Programmes of Study, Key Stage 3, England National Curriculum[1]:

"Pupils should be taught to:

- "use 2 or more programming languages, **at least one of which is textual, to solve a variety of computational problems; make appropriate use of data structures [for example, lists, tables or arrays];** design and develop modular programs that use procedures or functions
- "understand how instructions are stored and executed within a computer system; **understand how data of various types (including text, sounds and pictures) can be represented and manipulated digitally, in the form of binary digits**
- **"undertake creative projects that involve selecting, using, and combining multiple applications, preferably across a range of devices, to achieve challenging goals, including collecting and analysing data and meeting the needs of known users**
- **"create, reuse, revise and repurpose digital artefacts for a given audience**, with attention to trustworthiness, design and usability"[2].

[1] Statutory Guidance, announced in February 2012, National Curriculum in England, Computing Programmes of Study, Key Stage 3, for implementation (2013).

[2] The UK National Curriculum in Computing elements, highlighted in bold, are fulfilled by the "Literacy from Python" project.

The first steps taken (called Chapter 1 on the website) were originally, however, simply an experimental exploration of what might be done to contextualise the learning of Python, as we had done earlier for Scratch. Once the model had been conceptualised by the paper's authors as a possible cross-curricular working model, however, Beth (Beth Mead, a primary school pupil, then aged 11 years) and I set about developing further narrative scripts. The model was developed based specifically on the "Literacy from Scratch" model, and all of the Python coding was written by Beth. Largely self-taught, she used coding books [8], and online resources, such as the modified Turtle graphics example given in Chapter 3, shown later. Each Chapter added more Python elements as part of Beth's narrative scripts, and we created a website to share these thoughts (and the coding elements) with teachers. This thinking crystalised into the following set of project aims for the "Literacy from Python" project:

- To develop a cross-curricular project including simple story-writing skills and computer coding
- To develop elementary computer programming skills, using Python elements, such as strings and lists
- To provide support for UK Key Stage Computing courses (for ages 11 to 14 years) and GCSE Computer Science (for ages 15 to 16 years), and possibly for post-graduate teacher training courses
- To develop contextualised learning as a framework for teaching Python
- To create an educational support site, where teachers can download suitable, free classroom resources based on this teaching and learning model

The "Literacy from Python" project evolved, then, from an experiment with story-telling, which started in early 2018. Beth wrote the first short story using Python strings, set in a classroom, and involving her real-life pet dog, Maisy, and her Aunt Justine's cat, Malika. This project was itself the development of a series of short stories, "Stories for Children 2" that she had already written and published on the web, using Microsoft (MS) PowerPoint, to exemplify some basic computer coding concepts such as Algorithms, Abstraction, Decomposition, Generalisation, Logical Thinking, and If, Then, Else. These MS PowerPoint coding stories are posted on the "World Ecitizens" website as a free resource for teachers. There was then a delay, throughout 2018, while Beth and I worked together on some new projects using Scratch 2 and then Scratch 3, incorporating Sibelius music files with Lloyd Mead, at Lambeth College [9]. We returned to look at Python in 2019, to develop this storytelling idea further. Frustratingly, while positive discussions are currently underway with local schools and colleges, the classroom development of this work has, owing to severely restricted access to schools, been slowed by Covid[3].

While there is a useful (single) introductory lesson on the MIT Scratch website, showing how to download Python, there is, as yet, no material for developing story-telling using Python in the cross-curricular way suggested in this paper. The Python websites have methods for generating storytelling with Pandas ('The library called **pandas'** is a

[3] This teaching model was first accepted for presentation at ICET 2020 (Vancouver), but was later withdrawn because of health concerns caused by the Covid pandemic. Presentation of the paper was postponed, and later delivered by remote video link, at OCCE-IFIP 2021, for the TPEA.

Python package that provides data structures and is useful for structured and time-series data), but, once again, this is quite different from the creative, cross-curricular, constructionist, contextualised method of teaching and learning that we are advocating.

The accompanying Python website[4], developed to support this curriculum initiative, outlines several Python coding skills developed through creative narrative work, divided into very short Chapters or scripts. More elements are planned (see Fig. 10).

2 Method

In English lessons, or as an after-school homework, students aged 10 years and upward, will (post-Covid) be encouraged to create characters, and write a very short story which includes some dialogue - the "literacy" aspect of the project. This story can then be taken to the computer room, where, using Python, it can be reworked in the IDLE programming window, and printed out in the Shell window as an elementary Python program. This model therefore adds creative and cross-curricular elements to the computer coding process. In Fig. 1, the programming example can be seen, faintly, on the right of the illustration, with the instruction to print (in pink in Python – and on the website), with blank lines added as brackets () and the "table" imported, so that when the story is saved and "Run" as a program, the reader can choose a times-table which prints out within the story (in blue text in Python) in the left, shell, window. The "Literacy from Python" website provides a clearer, more colourful view.

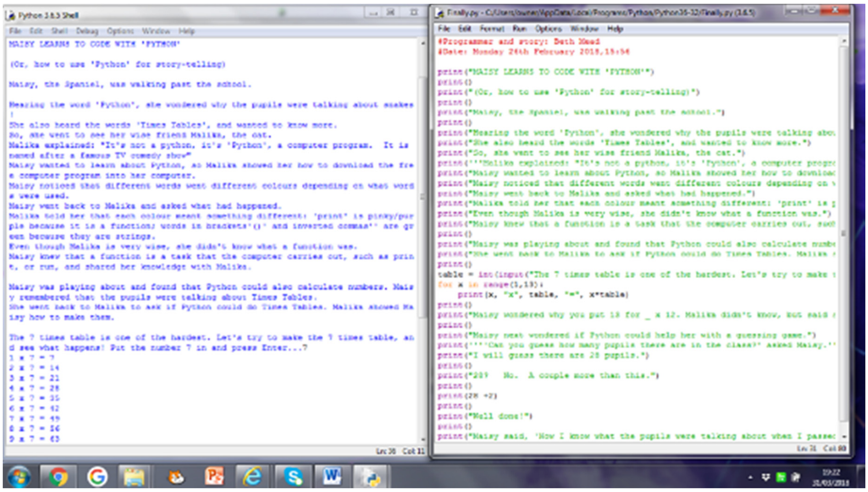

Fig. 1. Simple Python programming for storytelling and times tables. (Color figure online)

[4] The websites referenced in this paper can all be found using Google searches.

This process therefore combines storytelling, simple arithmetic (addition and times-tables), as well as computer programming. It is explained in fuller detail on the "Literacy from Python" website, together with the downloadable Python story files, for students and teachers to explore and develop in their own classrooms.

Fig. 2. Maisy, a real-life Spaniel

Maisy (Fig. 2) is one of the characters in the Python stories. She also appears in the 2017 storybook series that accompanies this ongoing project. Each story, originally in MS PowerPoint format, and free for use in the classroom, looks at a different element of computational thinking ("World Ecitizens" website). Some of these concepts are detailed below.

Computational Thinking

There is no single, agreed definition of computational thinking. It depends upon whom you ask - programmer, logician, or mathematician. There are, however, several generally agreed elements, and these are explored in these stories for children. For information on the choice of computational thinking concepts, these are shown in the resources developed by computing at school, and include:

- Algorithmic thinking (following a set of rules; sequencing skills)
- Debugging (detecting and correcting errors)
- Decomposition (breaking a complex problem down into simpler parts)
- Logical thinking (reasoning skills)
- Generalisation (recognising patterns, and using them to find solutions)
- Abstraction (sorting relevant information from unnecessary detail)

These concepts [8] are presented individually through these Maisy stories, and can be shown to pupils on an interactive whiteboard, or printed out for use in the classroom (see Fig. 3). They can then be discussed in class and incorporated into the narrative work before embarking on Python coding.

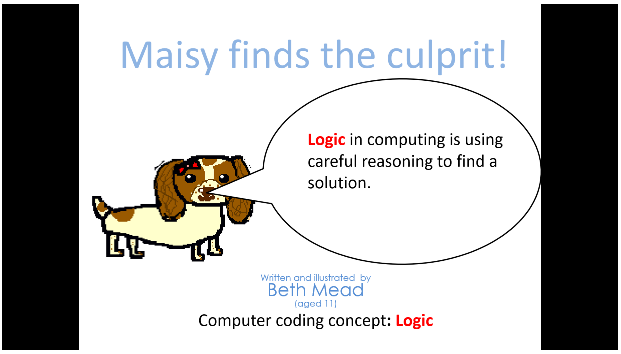

Fig. 3. A sample title page (one of six stories) exemplifying a coding concept

This teaching method has inspired us (Beth and myself) to develop the idea further, in addition to the MS PowerPoint method, above, incorporating more and more Python programming elements, as well as developing the storybook characters along the way [7]. "Literacy from Python" can be seen, therefore, as the latest development of a series of storytelling projects, which can be found set out in historical sequence, on the "World. Ecitizens" web site (see the homepage and scroll down: http://www.worldecitizens.net/).

The five-chapter story series, together with the Python elements is given below.

Chapter 1: Addition and Times Tables
Python Elements: Text Entry plus Importation of Times-tables

Using Python 3.6.5 originally (see the small text in the top bar of the Fig. 4 file), Beth created a children's story which introduced her animal characters, Maisy and Malika, to Addition and Time Tables within an imaginary classroom scenario. This teaching and learning process is further explained on the website, with practical hints for teachers (see Introduction and Teachers' Notes).

It is a creative, cross-curricular project that so far involves:

- English (writing short stories, including very careful punctuation)
- Mathematics (addition, times-tables, geometry – and we hope to add graphs later)
- Geography
- Art
- Computing (using Python coding, as a second coding language after Scratch)
- ICT (file management as part of computing)

Beth used the print text facility in Python to make the following short story chapters. It shows how Python sub-routines (a table, table = int) can be imported and used within a story-telling context. The text appears within the brackets in green, and "prints out" as blue:

```
table = int(input("The 7 times table is one of the hardest. Let's try to make the 7 times table, and see what happens! Put the number 7 in and press Enter..."))

for x in range(1,13):

        print(x, "x", table, "=", x*table)
```

This is found to be much easier than it looks.

So, she wrote the following story, called "Finally" on the website (Finally.Py) while still in primary school, Year 6, aged 11 years. This later became "Chapter 1" of the current larger computer coding project, "Literacy from Python", i.e. writing short stories created by using Python.

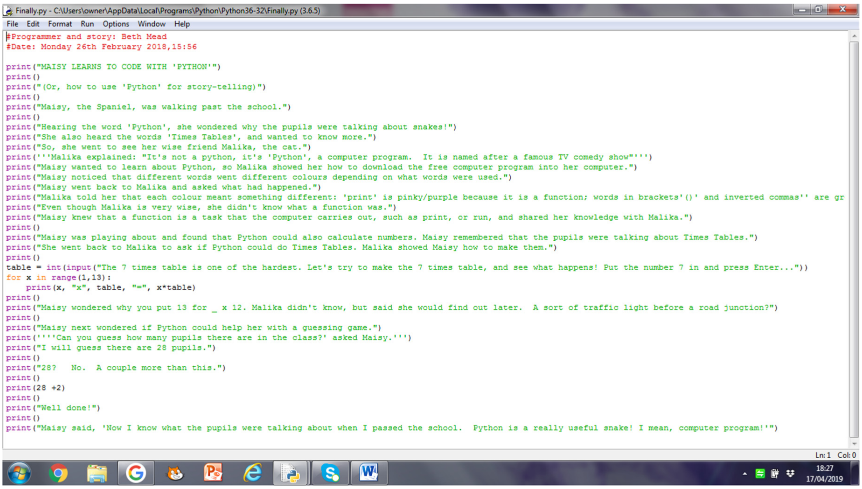

Fig. 4. With table included. (Color figure online)

Chapter 2: A Geometry Lesson

Python Elements: Text Entry plus Turtle Module

This Chapter looks at python for making geometrical shapes. (A year on from Chapter 1, we are now using version 3.7.2.) In the story, the animal characters learn to make a circle and a square, by importing turtle graphics (Fig. 5).

Here is an excerpt from the story:

```
print('''Malika said, "My friend Maisy and I have been working on Python.
We have been learning how to draw geometrical shapes.
Maisy, would you like to remind everyone how these look? How about a
circle and a square?"''')
print()
import turtle
window = turtle.Screen()
turtle.bgcolor("mintcream") #background colour of the window
turtle.color("olive") #stroke colour
turtle. begin_fill()
turtle. circle(80)
turtle.end_fill
from turtle import*
color("mintcream")
forward(50)
color("skyblue")
shape("turtle")
pensize(4)
forward(50)
right(90)
forward(50)
right(90)
forward(50)
right(90)
forward(50)
right(90)
```

The result of the above coding:

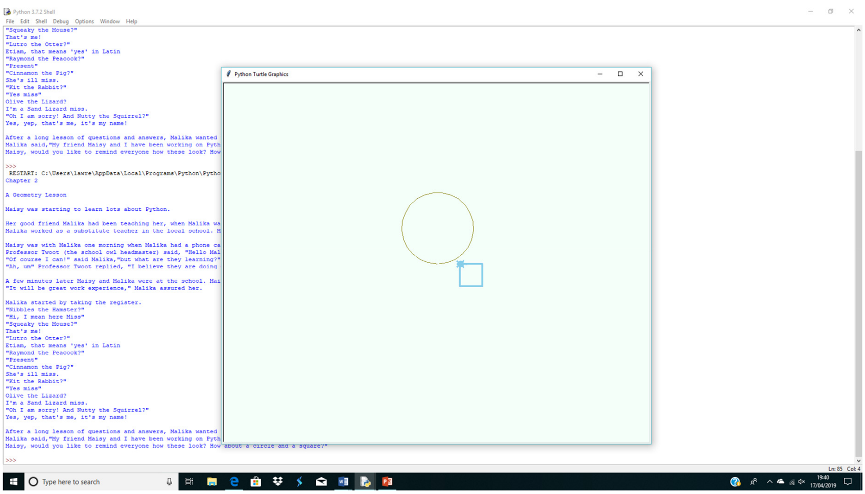

Fig. 5. Drawing a circle and square in Python, with the story and dialogue on the left

Chapter 3: A Biology Lesson
Python Elements: Text Entry plus Turtle Graphics
This Chapter was demanding. It is a biology lesson, with graphics. The story has a decorative flower at the end, thanks to inspiration from Aibek Toroev (a software engineer from Kyrgyzstan). There is a useful YouTube video created by Aibek Toroev, and with his coding later adapted by Beth, at: https://www.youtube.com/watch?v=ZsnKkyRCWR4.

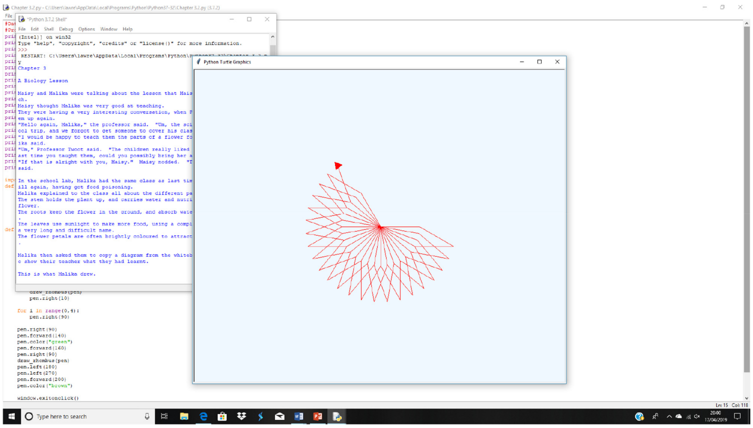

Fig. 6. The flower in progress (see the website file for the finished bloom)

As noted above, the England National Curriculum in Computing requires pupils to "**create, re-use, revise and re-purpose**" digital information, and Fig. 6 is an example of this requirement.

Chapter 4: A Geography Lesson (Quiz)
Python Elements: Text Entry plus If, Or, Else
The curriculum focus of this Chapter is geography, with a classroom quiz based on If, Or, and Else in Python coding (see Fig. 7).

```python
#Monday 1st April 2019
#Programmer Beth Mead
#Thanks to Ethan and Nate (testers)
print("A Geography Lesson")
print()
print("Malika is a very kind cat. She has always liked helping others in need, and so she is friendly with almost all of the teachers at the school.")
print("One morning the phone rang.  It was Miss Bindi, the Koala teacher of Geography, who came from Australia.")
print('''"G'day Malika," Miss Bindi said.  "Would ya mind coverin' my lesson t'day? It's the last day of school, and I'm goin' back t' Oz for the hol'days."''')
print('Malika, of course, said she would. She then called Maisy, who said she wanted to come, too.')
print('Maisy and Malika met outside the school gates.')
print('"So, what are we teaching today?" Maisy asked.')
print('"We are teaching the same class as usual, but we are teaching them Geography."')
print('''Maisy and Malika knew the class so well now they didn't even need to call the register. They just did it themselves.''')
print('They taught the class some general geographical knowledge. The class enjoyed the lesson very much.')
print('At the end of the lesson, Malika spoke to the class.')
print('"This is a quiz on what we have learnt." Malika said, "Remember you must NOT put Full Stops at the end, as the computer will mark it as wrong."')
print()
print()
print('"What is the capital city of France?"')
ans=input()
if ans=="Paris" or ans=="paris":
    print("You are correct!")
else:
    print("It's called Paris.")
print()
print('"What is the longest river in the UK?"')
ans= input()
if ans=="Severn" or ans=="severn":
    print("Well done!")
if ans=="Seven" or ans=="seven":
    print("Close, but it is spelt Severn.")
else:
    print("It's called The River Severn.")
print()
print("What are the four MAIN compass points?(Remember capital letters!)")
print("CLUE: put it in NSEW order.")
ans=input()
if ans=="North South East West" or ans=="North South East and West" or ans=="North, South, East and West":
    print("Correct!")
else:
    print("North, South, East and West are known as compass points.")
print()
print("Is the North or South pole colder?")
ans=input()
if ans=="north" or ans=="North" or ans=="north pole" or ans=="North pole" or ans=="North Pole":
    print("It's the south that is colder.")
if ans=="south" or ans=="South" or ans=="south pole" or ans=="South pole" or ans=="South Pole":
    print("Well done! Not many people know that.")
print()
print('Well done!  You have completed the quiz!')
```

Fig. 7. If, Or, and Else in Python coding

Chapter 5: A History Lesson - Illuminated Manuscripts
Python Elements: Text Entry plus Turtle Graphics

This was found to be harder than it looked. Angles were a challenge, but we were pleased with the result (see Fig. 8).

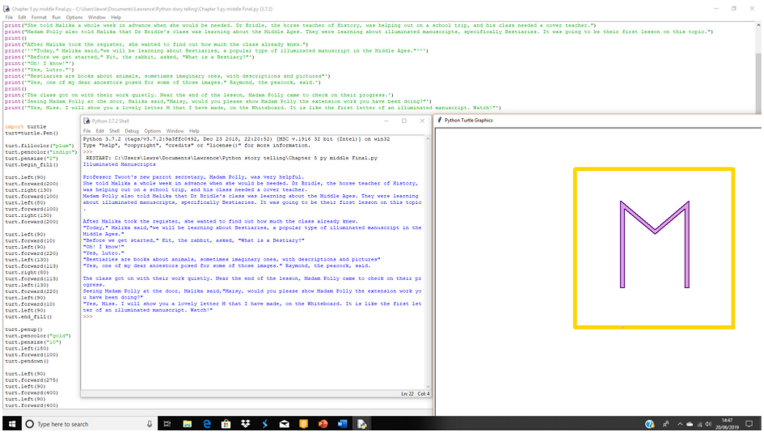

Fig. 8. Coding input with story output, and an "illuminated" letter M

This ended up as a Chapter about a history lesson. However, Beth and I had some discussion about it possibly being part of an English punctuation lesson (on capital letters) or possibly an art lesson (on calligraphy), or Mathematics (on angles).

3 Outcomes

The “Literacy from Python” project is steadily meeting its objectives. The teachers’ website (see Fig. 9) now has a series of five completed exemplar stories in short “Chapters” in which the animal characters, using Python, explore simple arithmetical concepts such as addition, and times-tables; a lesson in geometry; a lesson in biology; a lesson with a geography quiz (if, or, else); and using Python to create lettering (graphics). There are background and introductory notes for teachers, a MS PowerPoint file indicating the general teaching method, and links to related websites, including one on constructionism, on which the project is based. The project also supports the Programmes of Study for the England National Curriculum in Computing for Key Stage 3. So far (October 2021), the Python website has had over 1,000 visitors. How far the ideas posted there have been applied in schools remains to be seen: we have added a Contact Form to the website to support this evidence gathering.

Fig. 9. Literacy from Python website

This constructionist project therefore brings together many elements of the England school computing curriculum (including ICT skills, computer programming, and computational thinking), together with creative writing, elements of simple mathematics, geography, biology, and other curriculum subjects, all presented through storytelling (see Fig. 10).

	Literacy elements	Curriculum focus	Python coding elements
Chapter 1	Narrative, description, dialogue	Mathematics	Text entry; times tables
Chapter 2	Narrative, description, dialogue	Geometry	Text entry; Turtle graphics
Chapter 3	Narrative, description, dialogue	Biology	Text entry; Turtle graphics
Chapter 4	Narrative, description, dialogue	Geography	Text entry; If, Or, Else
Chapter 5	Narrative, description, dialogue	History	Text entry; Turtle graphics
Chapter 6 (pending)	Narrative, description, dialogue	TBC	Lists, loops, libraries, iteration

Fig. 10. Project elements and future plans

4 Future Plans

Further work is currently under discussion with local schools and colleges, with a view, post-Covid, to widening the number of students participating in the project, and to developing the number of computer coding concepts, such as loops or lists, within it. The initial project aims and objectives have, however, all been met: the constructionist/contextualised method is now clearly established through the exemplar stories; the supporting website has been started; and the dissemination of these ideas (through IFIP TC3 OCCE 2021Tampere) has begun. We need, next, to ascertain how many, and how easily, pupils can develop their own narrative script; create lists, loops, iteration and so on; and then integrate these elements successfully into their narrative scripts, thus contextualising their learning [8]. There are two curriculum levels possible for this development in England schools: at Key Stage 3 (ages 11 to 14 years), and within Key Stage 4 GCSE Computer Studies courses (ages 14 to 16 years), where a coursework element in coding is a requirement. It may also be a useful model for postgraduate teacher training courses in computer science. In this way, local school and college feedback can, in the future, be incorporated into the project and its website, and greater quantitative data about uptake of the model will thereby be generated to assist in evaluating the success, in wider practice, of the teaching approach suggested in this paper.

The international success of the cross-curricular coding project “Literacy from Scratch”, encourages our development of “Literacy from Python”, despite current progress being severely slowed by the Covid pandemic.

We hope that the free teaching materials on the now-integrated websites (“World Ecitizens”, “Literacy from Scratch” and “Literacy from Python”) may be of practical use in the classroom.

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Advocating for Educational Support to Develop Socially Disadvantaged Young People's Digital Skills and Competencies: Can Support Encourage Their Human Development as Digital Citizens?

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Abstract. Digital skills and competencies, and civic participation based on such skills and competencies (i.e. digital citizenship), are recognised as a challenge for the coming digital society. This paper contends that educational support to develop socially disadvantaged young people's digital skills and competencies has a positive impact on digital citizenship. Accordingly, findings based on four years of action research among a support group for socially disadvantaged youths in a provincial city in Japan and a discussion of the support's impact are presented. Our results suggest that such educational support can expand one's freedom to explore digital technology's potential, self-determination as an active learner in a digital environment, and space to participate in a digital society as a digital citizen.

Keywords: Digital skills · Digital competency · Digital citizenship · Computational thinking · Human development · ICT4D

1 Introduction

Common understandings of the significance of citizens' knowledge, skills, competence, and attitudes in relation to digital technology are reflected in frameworks and concepts developed over the past decade. Such frameworks provide a perspective on both simple digital technology use, and complex activities such as "communication and collaboration" or "problem-solving". Typical of these frameworks are the European Commission's Digital Competence Framework for Citizens (DigComp 2.0) [1] and UNESCO's Digital Literacy Global Framework (DLGF) [2], the latter based on a review of DigComp 2.0 and further investigation into global examples of digital skill frameworks. Both refer specifically to offering a comprehensive and synthesised competence model for digital technology use and for activities emerging from its use by defining several competence areas as targets for citizens' digital competence improvement. Digital citizenship is also a concept that focuses on citizens' knowledge, skills, competence, and attitude in relation to digital technology, but it stresses achieving and protecting citizens' rights of democratic participation in digital

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environments. The Digital Citizenship Education Handbook by the Council of Europe [3] introduces a conceptual model for digital citizenship based on the Council's 20 competences for democratic culture (CDCs). A UNESCO report [4] explains that a core competency of digital citizenship should address how to use digital technology in an ethical, safe, and responsible way, without restricting users' full participation in and contribution to the knowledge society.

Nevertheless, there are few empirical studies on whether and how the establishment of digital citizenship through digital skills acquisition might function to ensure citizens' rights and dignity, especially among socially disadvantaged people in developed countries with advanced digital environments. Among such studies, Kafai, Peppler, and Chiu [5] and Fields, Kafai, and Giang [6] suggest that: the acquisition of digital skills and competencies by citizens is the very social participation that digital citizenship is concerned with; gaps in social participation are strongly reflected in the encounter with programming in particular; educational support within schools and beyond can reduce participation gaps in digital skills and competencies. However, these studies do not highlight the changes that such skills and competencies can bring about in citizens' participation in society, particularly by expanding their freedom.

This paper's purpose is to discuss the actual impact of educational support on developing socially disadvantaged young people's digital skills and competencies (ESDC) in view of establishing digital citizenship. Accordingly, we address this subject using the human development approach (HDA), initially presented by Amartya Sen, which provides a holistic view in terms of fulfillment, well-being, and quality of life. One example of the HDA's practical use is the United Nations' Human Development Index, a composite index of achievements in human development [7, 8]. Uniquely, the HDA centers on expanding human capabilities [8]. In the context of HDA, capabilities represent the freedoms available to every individual, such as social, political, and economic participation, which equal full citizenship and the capacity to lead the kind of life she/he values [9–11]. Deprivation of these capabilities is considered equivalent to poverty [12, 13]. From an HDA perspective, we ought to understand an individual's educational attempts in terms of the development of capabilities, i.e., the expansion of the freedoms that an individual with full citizenship can enjoy to realise a life worth living.

Hence, this paper presents a research study into the human developmental meaning of ESDC for socially disadvantaged youths living in a mid-sized provincial city in a developed country. For this purpose, the author both engaged in a support group activity to aid the social participation of young people experiencing social withdrawal or school absenteeism and conducted a participatory study to help such young people with their learning about computing. The study addressed the research question: How could ESDC encourage disadvantaged young people's human development as digital citizens?

2 Relevant Literature

This research was motivated by an ethical concern to promote social participation equity through the development of digital skills and competencies. Promoting equity in social participation has been a topic of debate in digital divide studies [14]. Early discussions based on techno-optimism insisted on digital technology's potential for social equalisation [15]. However, at the beginning of the 2000s, sociological arguments pointed out the limitations of technological determinism (see [14]). For instance, Norris [16] asserted that computer access, cultural background, ethnicity, and literacy would become critical elements in the digital divide, i.e., inequality produced by a social gap that determined who successfully benefited from digital technology and who did not. "Digital equity" was derived from these digital divide arguments, which stressed an ethical viewpoint that problematised social inequities in involvement with digital environments (see [17, 18]). Gorski described digital equity as a "social justice goal," focusing on the environment that causes the gap between advantaged groups and others, [11] based on comparative research into young children's computer use among schools with different socioeconomic status and cultural backgrounds.

In pursuit of digital equity, this study focuses on the potential of ESDC to empower young people in a supported group. We focus especially on computing skills as the underpinning of digital skills and competency, which we define as the ability to use computing functions actively for self-defined purposes such as problem-solving and play. This definition is strongly related to "3. Digital content creation" and "5. Problem-solving" in DigComp 2.0 [1]. We also refer to the thinking skills underlying such computing skills as computational thinking. The definition of the latter for our purposes follows competence 5.5 of the DLGF [2]: "To process a computable problem into sequential and logical steps as a solution for human and computer systems." Previous literature deemed lack of skills in the use of digital technology as a possible factor broadening divides in social and political participation [19, 20]. This suggests the significance of educational approaches to close the divide. However, literature debating the digital divide in a sociological context has focused on gaps in the availability of information among different social classes, and thus, considers Internet access and information acquisition skills the main issues. By contrast, we focus on the contribution of productive digital skills and competencies to civic participation in digital environments, such as the aforementioned computing skills and computational thinking.

This study also highlights the expansion of "freedom of choice" to reflect human development. "Freedom of choice" represents what a person can choose in each real-life context. The exercise of this freedom corresponds to Kleine's choice framework [21, 22], developed to assess ICT4D (ICT for Development) outcomes. Previous literature on ICT4D (see [23, 24]) has shown ICT's benefit to improve the living conditions of disadvantaged people in rural communities. ICT, including legacy information systems, such as analog telecommunications and the digital network of the Internet, has been observed and conceptualised as a critical factor for community development that improves residents' poor life conditions by expanding their freedom of choice for living.

From the perspective of Kleine's framework, ESDC should be recognised as a means of expanding digital technology's impact on local community members' circumstances. During the development of the ICT4D study, the focus both in research and actual development moved from technology-centered "passive diffusion" toward resident-centered "active innovation" [25]. In response to this shift, assessment frameworks for ICT4D, which incorporated Sen's HDA view, emerged to describe the development of residents' living conditions [22, 26]. Kleine's choice framework [21] was among those that attempted to identify ICT's contribution toward specific development goals by observing individuals' freedom of choice. The choice framework featured the "enormous potential" of digital technology represented by ICT to facilitate individuals' freedom of choice. Then, to address the actual conversion of this potential into a freedom, it highlighted the comprehensive and plural relationships among several factors such as social structure, agency, dimension of choice, and development outcomes [21]. Our study's focus was thus on active innovation concerning freedom of choice among the supported young people and other support group members, stimulated by ESDC. In particular, we attempted to observe the promotion of young people's freedom as demonstrated by their attitudes as digital technology learners and users, which Shonfeld et al. [27] conceptualised as digital agency acquisition. Our study also aimed to provide an otherwise rare example of ICT4D in a developed country.

3 Methodologies

The study chose action research (AR) as a participatory research methodology. This approach enables participants to find effective solutions to problems they confront in their lives [28] and seeks positive social changes based on democratic values [29]. In AR, researchers and other participants need a shared vision for the process and goal of problem-solving, and learning through shared reflection is most critical in this process [30]. The AR process was implemented in a support group for disadvantaged young people in a rural city in Japan, a developed country. With the cooperation of group members, we worked together to establish ESDC as a new option for supporting young people's social participation. This paper focuses particularly on the findings of a reflective exercise conducted from an HDA perspective on the significance of ESDC.

The author engaged in the group's activity, aiding the rehabilitation and social participation of youths who had experienced social withdrawal or school absenteeism, to conduct a participatory study. The group met in a mid-sized provincial city, and varied in size during the study period from five to ten young people with two to five staff members, either full-time or part-time. The author acted as a part-time supporter, assisting youths in learning various things about computing and informatics. The author collected data in the form of field notes, a series of text descriptions with some pictures and movies, noting events and occurrences, dialogues with the participants, findings and interpretations, and reflections on every session during the study period.

The study commenced in May 2015, following a similar pilot study from December 2013 to January 2014, and finished in March 2020. Findings are based on analysis of field notes from May 2015 to February 2018. During this period, the author and the youths in the group were involved in introductory computing and informatics learning through practices such as making games, teaching older adults programming with Scratch, constructing a programmable robot called MugBot[1], and practising introductory programming with the C and Ruby languages.

[1] MugBot is a nonproprietary, open-source social robot originally designed by the Koike Laboratory in Tokyo Metropolitan University. http://www.mugbot.com.

Data were coded by thematic analysis [31, 32] to highlight the research question's essential factors. The coded data contains field notes for 66 days taken from May 2015 to February 2018. For this coding, the author scrutinised the field notes to identify themes capturing important facets of the data related to the research question [32] and concepts relevant to explaining the themes. The author then reinterpreted the coding results to determine themes and issues essential to the research question. This process was supplemented by further observations and dialogues in the field. Full ethics approval was obtained from the Research Ethics Committee of Seisa University (No. 1613).

4 Findings

Based on the data analysis, the author identified four thematic topics as those that gave insight into the research question: (1) ESDC stimulated the youths' motivation to learn computing skills and knowledge autonomously; (2) Computer programming led the youths to the joy of thinking computationally; (3) The youths learned more actively when the author behaved as a co-learner rather than a teacher; (4) The youths' computing capacities augmented their expected roles in the group.

4.1 Autonomous Participation in Learning Computing Skills and Knowledge

Participation in ESDC by youths in the support group should be characterised as a sign of "autonomy"—an autonomous attitude toward learning computing skills and knowledge. For example, one youth, who was late 20s and had experienced school drop-out and social withdrawal ("Y1" for anonymisation), attended the computing workshop, organised by the author at the group's office almost every Thursday afternoon, alone every week. Attendance at the workshop was left optional for every group member. Although it was rare for Y1 to express motivation to participate in the workshop, Y1 did occasionally show a will to continue learning about computing and to practice independently whatever interested them in the workshop. The author found this "autonomy in learning" during the workshop to be valuable in human development because most participating youths had been more or less deprived of this autonomy by their drop-out experiences. Below are excerpts from the field notes (originally written in Japanese) suggesting Y1's autonomous participation in learning computer programming (Tables 1 and 2).

Table 1. Excerpt from field notes, June 15, 2017

*(This is the answer Y1 gave to a question from a group staff member asking the motivation to learn computing. ** signifies the author's name.) "Maybe if ** cannot visit here, I think I will open the PC by myself and do something with it." (June 15, 2017)*

Table 2. Excerpt from field notes, July 13, 2017

By the way, from Y1, the decision to learn Ruby language after C language was clearly stated. C and Java, according to Y1's examination, are the languages that "learning cost" is high and should be avoided as a learning object, and learning Java after learning C seems complicated for Y1. (July 13, 2017)

Y2, who was also late 20's and had experienced school drop-out and social withdrawal, had been a supported member of the group and participated in the author's workshop to learn computer programming for one year. Y2 then stopped attending the group (for reasons that included getting a part-time job and starting a high school correspondence course). Subsequently, Y2 suddenly visited the group's office and described their decision to learn programming again, in response to the author's invitation (Table 3).

Table 3. Excerpt from field notes, February 15, 2018

*Today, Y2 will join the workshop again. I received a message about that from S1 (the chairman of the group) this morning. Y2 visited ** last week. At that time, ** invited Y2 to learn computer programming again. Y2 seems to have captured it positively. (February 15, 2018)*

4.2 Computer Programming Leading to the Joy of Computational Thinking

The experience of computer programming in the workshop seemed to lead youths to feel the joy of thinking computationally. The author featured computer programming as the workshop's main content as it would allow learners to use active and creative thinking. In particular, they go back and forth between their imagination and sequential and logical ideas to solve their problems, which might correspond to computational thinking as defined by competence 5.5 of the DLGF. This happened in the workshop, and the youths seemed to be motivated mainly by the joy of writing and executing the programs they made. Programming especially appeared to give youths room to reasoning about a problem, express their ideas, obtain immediate feedback through executions, and to debug if errors occurred. This process seemed valuable from a human development viewpoint as, through computer programming, youths regained the joy of active thinking they had previously lost. The excerpt below describes this (Table 4).

Table 4. Excerpt from field notes, May 11, 2017

When Y1 tried to give a hint about the execution result of the program S2 (one of the supporting members and also one of the participants in the workshop) made, S2 said, "Don't say that, don't say that, please!" However, it seemed that S2 had heard the hint after all. S2 said "boring (with a laugh)" after hearing it. S2 seemed to have enjoyed thinking alone (that is, S2 loved to solve problems without help). (May 11, 2017)

Typically, in Y1's case, computer programming encouraged a more profound interest in computing and thinking computationally. When the excerpts below were written, Y1 had experienced programming for more than one and a half years with Scratch, Ruby, JavaScript, and C languages. Y1's programming skill level was not extremely high (though it seemed better than that of the average freshman undergraduate). By creating and debugging small pieces of programs, however, Y1 could enjoy reasoning about the cause-and-effect relationship within an algorithm and applying their understanding of the algorithm to new situations (Table 5).

Table 5. Excerpt from field notes, December 7, 2017

*Y1 used the program they created just now to calculate the difference from 0:0:0 AM to 23:59:59 PM and told me that "the number of seconds in a day is ...." Y1's use of imagination to get interesting results by creating and running programs made me feel Y1's computing affinity. Probably, such imagination came out because Y1 had developed ideas of computing while programming to some extent. ** thinks the thought that produces such computing ideas may well be called computational thinking. (December 7, 2017)*

4.3 Supporting the Youths as a Co-learner Rather Than a Teacher

Providing support as a co-learner was key to the supporter's attitude when helping youths to learn digital technology. Youths seemed to learn more actively when the author behaved as a co-learner rather than a teacher. When the workshop started, the author acted as a teacher rather than a co-learner because the youths who were interested in or joined the workshop were all complete computing beginners. The author thus had to teach many things about computing and computational thinking, which resulted in the author adopting the attitude of a teacher. This attitude, however, sometimes led workshop participants to adopt a passive learning role. Y1 in particular expressed apparently negative responses, typified by the excerpt below, toward something the author recommended that Y1 should learn next (Table 6).

Table 6. Excerpt from field notes, March 9, 2017

*** explained the outline of the HCP Chart[a] and said, " I think that this is a big learning point, isn't it?" In contrast, Y1 muttered in a small voice, "I do not want to do it." Then, as an outline, ** explained, "The most important thing is that it enables us to show the purpose and means firmly, in the flowchart you will only write means." Y1 put down a book and said, "I do not understand." (March 9, 2017)*

[a]An HCP Chart (Hierarchical ComPact description chart) is a notation system for designing program structures developed by Yokosuka Electrical Communication Laboratory Nippon Telegraph and Telephone Corporation (currently NTT). See [33]

Conversely, when the author behaved as a co-learner who was tackling the same problem as the youths participating in the workshop, their attitudes to learning computing skills and knowledge seemed to become more active and even autonomous.

Learning over time, the author tried to express a manifestly "co-learner attitude," sitting beside the learners in what the author regarded as a "co-learner position." The excerpt below describes the author's reflections on practicing programming alongside the youths in the workshop (Table 7).

Table 7. Excerpt from field notes, February 1, 2018

*As soon as Y1 saw the state that ** got an error saying "Hmm...," Y1 immediately looked into **'s PC monitor. As ** expected, sitting in the co-learner position seemed to make it easy to create a cooperative (?) learning space. Then Y1 began to tell their progress of the same problem spontaneously. (February 1, 2018)*

4.4 Computing Capacities Augmenting the Expected Roles

As youths' computing capacities grew, their expected roles in the group expanded accordingly. This amplification of roles accounts for human development in terms of expanding the capacity to participate in real society. S1 expected Y1 and Y2 to contribute to organising elementary computing workshops for children as facilitators. In practice, such workshops were not realised. However, the author saw several times that Y1 personally undertook the role of introducing programming to the group's newcomers, as the excerpt below describes (Table 8).

Table 8. Excerpt from field notes, December 21, 2017

*Currently, in front of **, Y1 introduces Scratch programming for the visitor. [...] Y1 is doing it for the visitor just by their own decision. (December 21, 2017)*

Y1 also helped the author several times when the author faced problems in coding during the workshop. Judged by performance, Y1 became more knowledgeable about C language functions after several months' learning. It was therefore natural for the author to sometimes ask for their help during the workshop as a co-learner, which granted Y1 a new role in addition that of learner in the workshop. Below is the excerpt, which reveals the author's recognition of this pattern (Table 9).

Table 9. Excerpt from the field notes, November 9, 2017

*Today's workshop saw more scenes that ** asked for help that ** would like to be taught by Y1 (and actually taught) than the scene ** taught something to Y1. [...] Y1 was obviously more enthusiastic regarding searching for C language system functions, and as a result, Y1 came to acquire more knowledge of C language than ** which could be utilized for problem-solving. [...] In other words, the relationship between Y1 and ** at this workshop became clearly closer to the relationship that supports each other in learning just as "co-runners with learning." (November 9, 2017)*

During the study period, the group began to consider undertaking a website development project for a local shopping mall association with which the group had a close relationship. The author was asked to advise about utilising the project for Y1's job training and agreed to supervise it. Y1 was invited to join the project as the primary coder and accepted this role. Below is an excerpt of a discussion log involving S1, Y1, and other group staff (Table 10).

Table 10. Excerpt from field notes, September 14, 2017

S1 wants to use Y1's skills to create a chance for him to participate in society since Y1 is studying a lot at the workshop. S1 thinks it desirable if such a chance is created not purely inside the group's daily activities but within the relationship between the group and the surrounding societies. [...] *What is the structure (of the website development project)?* *· S3 (another staff member) is likely to be in charge of management [...]* *·Y1 will be in charge of the production, and S1 also wants to be involved in the production with Y1 if possible. (September 14, 2017)*

5 Discussion

What bearing do the above observations have on the question of ESDC's capacity to encourage the development of digital citizens? In terms of human development, ESDC could encourage the human development of disadvantaged youths as digital citizens by, for example: (a) expanding their freedom to explore the potential of digital technology by themselves; (b) stimulating their self-determination as active learners in a digital environment; (c) expanding their space to participate into a digital society.

Concerning point (a), ESDC could help disadvantaged youths to expand their freedom, described by Sen as the opportunity and process of choice [34], to explore the potential of digital technology by themselves. This argument reflects findings (1) on autonomous participation in learning computing skills and knowledge and (2) on the joy of computational thinking. In the author's eyes, this argument implies that such educational support may act as a potential liberator for participants from imposed uses of digital technology. Participants may then expand their computing capacity, regain their freedom of choice in learning about digital technology, and create new technology uses for their own interest. During the workshop, the author took care not to give firm recommendations to participants concerning pragmatic uses of their computing skills and knowledge, such as acquiring job-related skills or qualifications. For the participants, learning computing in the workshop seemed to involve just a spontaneous enjoyment of the freedom of exploring the potential of computing. They seemed to become creative thinkers as they tackled programming problems or made open source robots. The youths' achieved what should be regarded as an expansion of Sen's capability, representing a person's enjoyment of the opportunity to do or be what she/he values [9].

While point (a) focuses on the learning opportunities of digital technology, point (b) illuminates a broader perspective on learning activity itself. Findings (1) and (3), the latter of which relates to the supporter's attitude as a co-learner, suggests that such educational support could assist disadvantaged youths to gain self-determination as active learners in a digital environment. The learner's shift toward self-determination may have multiple causes, however, the expanded freedom of exploring digital technology, shown in point (a), is undoubtedly a significant trigger. Self-determination as a learner in a digital environment signifies readiness to become a digital citizen possessing sense and use of choice, especially the choice to participate in a digital society that Kleine argued is an essential part of the dimensions of choice [21]. Moreover, the shift also indicates that such educational support corresponds to problem-posing education, which Paulo Freire [35] conceptualised as a liberating education model for oppressed people to become self-determining learners in a digital society.

Point (c) is derived from finding (4) on the expansion of youths' expected roles in the group. As (4) shows, ESDC could encourage disadvantaged youths to acquire new roles in their community as a result of their enlarged capacity to utilise digital technology. During the research period, the supported youths, who were initially novice computing learners, came to acquire new roles, such as workshop facilitator, co-learner in computing, and coder in a website development project. The acquisition of digital skills and competencies by youths expanded the choices available to them both within the group and in the surrounding community. This sort of role expansion inevitably occurs in a contemporary society that is filled with the need to utilise digital skills and competencies in problem-solving and is crucial in strengthening the individual's ability to live as an independent citizen in a digital society.

Role expansion among the youths in the support group was essentially an achievement of ESDC's development goal to contribute to the supported youths' social participation. Judged by the choice framework [21], this achievement was a result of input from the following individual agency-based capability factors: education resources (e.g., the computing workshop); information (e.g., textbooks, web resources, the author's suggestions, etc.); material resources (e.g., computers and other devices the group offered); and social resources (e.g., the group's membership). The achievement was also affected by structure-based capability inputs such as institutions and organisations (e.g., the support group, the local shopping mall association), formal and informal laws (e.g., the NPO law to support non-profit organisations, daily rules held by the group's members), and access to ICT. In the ICT4D context, skill enhancement in ICT use is considered to expand residents' choices and opportunities to live in society [36].

6 Conclusion and Limitations

The findings of this paper reaffirm that ESDC has the potential to solve social problems pertaining to digital equity. Furthermore, this study has revealed a need for inclusive educational support for socially disadvantaged people in local communities. This is the third area, after schools and families, in terms of skills and knowledge of digital technology and the capability to learn digital technology independently. In this context, pedagogical studies of the relationship between computer programming and learner's self-determination in learning, as Seymour Papert argued in his chapter "Computers and Computer cultures" [37], are a focal point for considering the learning content of such support. Moreover, the author argues that the ICT4D research approach is valid even in developed countries and that it should be pursued more actively, focusing not only on the diffusion of ICT infrastructure but also on the provision of educational support. The author believes that this study is a leading example of addressing this issue.

It must nonetheless be emphasised that this research is a qualitative study based on a small sample. One should therefore be cautious about generalising the research outcome. The results must be read critically, especially in light of different socio-cultural factors, diffusion of digital technologies, and educational circumstances surrounding digital skills and competencies.

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Developing Inclusive Digital Pedagogies: Reflections on the Past, the Present and Future Directions

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Abstract. Disabled children's experiences of using digital technologies in mainstream classrooms are very mixed. On the one hand, children's rights and digital rights legislation and inclusive education policies have promoted inclusive and equitable pedagogical practices for decades. Digital technologies are becoming increasingly prevalent in homes and schools, a phenomenon rapidly accelerated by the global Covid-19 pandemic. Despite this positive rhetoric, the reality on the ground is that inclusive digital pedagogies – that prevent disabled children experiencing exclusionary educational practices in mainstream classrooms – are underdeveloped and require significant research and development. Current uses of digital technologies by disabled children, harnessing accessibility features in mobile technologies, can focus attention on their differences. Digital technologies in classrooms generally are often used in mundane ways which do not make the most of opportunities for creativity, collaboration and student-centred learning. This paper reflects on the situation in the past and present in relation to the impact of disability studies, children's rights, policies on inclusive education and, digital technology developments and educational practices, on the development of inclusive digital pedagogies. It concludes by outlining early findings from a research project carried out in North West England that identifies challenges in relation to the development and implementation of inclusive digital pedagogies.

1 Introduction

Inclusive education and digital use practices have a great deal in common in their lack of realisable promise. Inclusive education has a disappointing legacy in mainstream schools. Typically, disabled children and young people are integrated but then experience ongoing exclusionary practices. These compromise the positive values of inclusion within the very environments expected to welcome and support them. Likewise, digital use practices - children's uses of digital technologies to support formal learning - have frequently been integrated into schools but not well embedded into pedagogy, often replicating learning practices in mundane, uncreative ways. This situation has formed a stark comparison to the more exciting and innovative uses and

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experiences outside of school including at home. The implications of the impact of the pandemic on digital practices and inclusion in the longer-term remain to be seen following the shift to emergency remote learning then subsequent re-entry into schools. This means that we are at a fulcrum, a critical and potentially transformational moment in time, for reflecting on and learning from the past; taking stock of the current; and making recommendations to build more innovative, effective and inclusive digital pedagogies in future. Keeping this in mind, this paper will introduce disabled children's childhood studies perspectives to situate this paper at the intersection of disability studies and digital education. It will reflect on the past via the development of disabled children's practices in mainstream schools in the context of children's rights and inclusive education over the last four decades alongside development of inclusive (digital) pedagogies. Secondly, it will explore the current situation in the context of the newly introduced children's digital rights amendment; the apparent emerging trends towards the development of inclusive (digital) pedagogies; the opportunities provided by mobile technologies; and the potential opportunities triggered by the pandemic. Third, it will consider future directions and conclude that more research and development is needed. In light of this, it will introduce early findings from a current project with teachers to develop effective inclusive digital pedagogies to support disabled children and young people's digital use practices to learn post-pandemic in inclusive education settings. By bringing these perspectives together, we will be able to provide a platform to consider how best to support disabled children with digital technologies within inclusive educational environments in the future.

2 Disabled Children's Childhood Studies and Digital Education

This paper is written from a disabled children's childhood studies perspective drawn from disability studies and founded on three main principles: a) disabled children should not be automatically conflated with impairment and vulnerability; b) disabled children's voices should be placed at the centre of research designs; c) an agenda for change is essential given the need to challenge the authority of the 'norm' [1]. The first author has adapted the principles in relation to disabled children's digital use practices [2] as follows: i) digital activities should enable all children in the class to learn; ii) disabled children should have the same opportunities to benefit from digital use practices as their non-disabled peers; (iii) digital use practices should be inclusive, not intensifying differences between children or creating stigma; (d) class teachers should be supported to develop inclusive digital pedagogies; (e) research should explore and develop disabled children's digital use practices to enhance their learning and their lives more generally. Reluctantly, the term 'SEND,' to describe children with special educational needs and disabilities is used in the paper to reflect its dominant currency in policy and schools while recognising that associations with being 'special' and having 'need' [3] are more aligned to the medical than the social model.

3 Reflecting on the Past: Developing Inclusive (Digital) Pedagogies

3.1 Children and Human Rights Legislation

Human rights legislation underpinned the shift to inclusive education. In particular, the UN Convention on the Rights of the Child (UN CRC) [4] was instrumental in supporting children's rights. Article [2] of the (UN CRC) stated that all children have the right 'to receive education without discrimination on any grounds' [4, p. 14]. This was reinforced by the UN Convention on the Rights of Persons with Disabilities (UN CRPD) [5], emphasised within Goal 4 of the United Nations "Sustainable Development Goals" with the intention being to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [6].

3.2 Inclusive Education

The driver for global inclusive education since the 1990s has been the Salamanca statement [7]. It sought to distil human rights legislation into practice by urging each country to develop a comprehensive educational strategy that emphasised 'special needs education.' It was argued that 'ordinary' schools needed to be reformed given their importance to include: 'everybody, celebrate differences, support learning, and respond to individual needs. As such, they [schools] constitute an important contribution to the agenda for achieving Education for All and for making schools educationally more effective' (p. iii). The Salamanca statement was integrated into many countries' educational policy, oft seen as a mechanism for promoting social justice and improving society as a whole via access to education in high-income countries within Europe, Australasia and North America.

In practice, the impact of inclusive education has been disappointing. Taking the UK as an illustration, policy introduced in 1978 specified that disabled children should be educated 'wherever possible' within mainstream settings [8, 9]. This was followed by the SEN [Special educational needs] Code of Practice [10]; the Social Exclusion Task Force [11]; the Children and Families Bill [12]. Yet, successive governments, researchers and activists have consistently identified failures in implementation. Inclusion in schools remains underdeveloped reflecting integration rather than inclusion [13]. Schools have been unable to develop an inclusive ethos whereby inclusion is recognised and embedded in all aspects of activity. The role of the teacher is key to this but instead of planning inclusive lessons, many class teachers do not design lessons from the outset that take 'primary responsibility' for the disabled children and young people in their classes [14]. Instead, disabled children are frequently stigmatised and marginalised, denying their independent access to the curriculum. Teaching assistants and other support staff are relied on to "'bridg[e]' the learning in the moment" [15]. When this happens, staff responsibilities can be unclear or overlapping; teaching assistants can be called on to mediate the teacher's pedagogical approach.

Evidence has shown that the limited uptake of inclusive pedagogies results from a range of difficulties. This includes a lack of useful guidance underpinned by research that can be introduced to teachers during initial teacher education programmes and via in-service professional courses, to enable teachers to develop the skills and knowledge they need. Moreover, heavy teacher workloads and related time constraints limit both the opportunity for teachers to access this training or to incorporate inclusive pedagogies into their lessons even when they are able to see the potential for this approach.

3.3 Digital Education

The introduction of digital technologies into schools has also been somewhat disappointing (up until the point of the pandemic where longer-term changes to digital use practices and implications are not yet knowable). There has been much promised about the potential of digital technologies to support disabled children, offering them incomparable opportunities to facilitate independent access to the curriculum and learn alongside their peers [16]. This is particularly evident when inclusive digital pedagogies are adopted that enable 'teaching and learning activities whereby class teachers have designed lessons for all children from the outset using digital technologies, thereby facilitating independent access to the curriculum for disabled children' [2, p. 11]. Yet, successive studies have shown that digital practices in schools by children are often uncreative and dull. While some pockets of innovative and creative uses of technologies clearly exist, many reflect traditional teaching practices rather than enabling the development of more innovative digital pedagogies that could enhance and revive the curriculum. For example, limited digital practices such as Excel for tables and graphs, PowerPoint and word processors for writing have often been reported [17]. These typical 'office' uses are in contrast to the potentially more collaborative and student-centred learning approaches that digital technologies can afford. In the last decade, possible opportunities that are more exciting have arrived with the increased use of mobile devices in schools. These are potentially really useful for disabled children due to in-built accessibility functions. Researchers quickly observed that the use of well-chosen apps were received positively by young people [18]. Yet, since then mobile devices have been criticised and banned [19]. The continuation of mostly mundane digital use practices undermines the opportunities for disabled children to take part in expansive, engaging and innovative activities alongside their peers. Instead, mobile devices have been used mainly as assistive technologies by disabled children thereby potentially stigmatising them and highlighting individual differences between children [20].

3.4 Developing Inclusive (Digital) Pedagogies

A key issue within debates in the past has been that teachers are rarely introduced to disability studies in education to support positive change [21]. Alongside this, there has been an accompanying lack in guidance available to teachers about how to develop pedagogies that reflect the underlying beliefs, values and attitudes of inclusive education [22]. Important exceptions are, for example, the 'Index of Inclusion', a set of resources for schools to develop inclusive practices [23]. Florian and Spratt also developed a model for use in teacher education [22]. This was a holistic model built on themes of learning, social justice and every teacher's role as an 'active professional'. They argued the need for a set of underlying principles that enable teachers to develop the knowledge and skills they need to provide meaningful learning with the same opportunities available to all children.

In relation to the development of inclusive digital pedagogies, this area has been underdeveloped with little attention given to digital use practices in situ in the context of inclusive education policy. There have been studies and evaluations of particular software or hardware; or interventions aimed at improving specific learning outcomes such as learning and independence [24]; communication, organisation and social skills [25]. Some providers and educators have also generated useful lists of accessible apps for disabled children to use. But in general, there has been very little research about how disabled children use technologies for learning in situ in ways that embed the underpinning beliefs and values of inclusive education with associated guidance for teachers about how to implement this.

4 Exploring the Current Context

We are now at a critical moment in time. To take stock of this key moment, a review is presented of the current state of play of each of the key categories of children's and human rights, inclusive education, digital education and stage of development of inclusive digital pedagogies. This will provide the foundations to make recommendations to build more innovative, effective and inclusive digital pedagogies for the future.

4.1 Children's and Human Rights Legislation

The United Nations Convention on the Rights of the Child General Comment No. 25 [26] recommends four general principles. Firstly, children should not be discriminated against and should not be excluded digitally. Secondly, the best interests of the child should guide the development of any online provision. Thirdly, children should be protected from risks to their 'life, survival and development'. Finally, digital technologies should be harnessed so that children can express their opinions and give their views on matters that relate to them. The importance of digital technologies in supporting children's learning is highlighted including access to educational resources, teachers and peers, and opportunities to continue learning outside classrooms. The General Comment also notes that digital technologies can address barriers that disabled children face and that attention should be paid in schools to ensuring that new barriers are not introduced by offering them assistive technologies, multiple formats of digital resources and meeting the principles of universal design.

4.2 Inclusive Education

Despite policies in all four UK nations that promote inclusive education, in reality progress has remained slow [27] as it has been internationally [28]. Since the introduction of the Children and Families Act in 2014 in the UK, disabled children can access support through an education, health and care (EHC) plan if they are assessed to need more 'special educational needs' support than can be routinely provided by the school. However, despite this provision, a House of Commons government Education Committee report in 2019 stated that current policy, the Children and Families Bill (2014), had ‘let down’ a generation of children and young people [29]. Implementation had resulted in buck-passing, lack of general accountability, shortage of the resources available and a bureaucratic nightmare. More recently, a parliamentary report [30] concluded that ‘Mainstream schools have little financial incentive to be inclusive of pupils with SEND [Children with special educational needs and disabilities] (p. 6). This suggests that inclusion in the UK at least currently remains problematic.

4.3 Digital Education

Many schools across the globe were generally unprepared to meet the challenges posed by the pandemic and in particular the necessity to support their students’ remote learning. Teachers, both experienced and inexperienced with digital pedagogies, were forced to move teaching online with little time for planning and developing best practice [31]. Initially, there was little synchronous interaction (e.g. ‘live’ lessons) as schools investigated safeguarding issues and were cautious not to exclude students due to lack of technology access [31]. The pandemic compelled parents and carers to become more involved in supporting their children’s learning. This obligation came with great upheaval and anxiety for all citizens with the societal move to a lockdown situation, with parents and carers facing competing demands on their time and feeling that they lacked the knowledge to undertake this new role [31].

The shift to emergency remote online learning has provided unique opportunities for effective, innovative solutions to be identified, created and scaled, albeit over a period of many months as schools rushed to develop remote learning strategies, invest in new technologies and provide professional development for their staff. As noted earlier, research carried out pre-pandemic has shown how digital practices outside of school settings are often more expansive and engaging than the typical, passive uses of technology in schools [32]. Yet in school, mobiles devices, for example, have often been criticised and banned [19]. Therefore, it is essential that we know how emerging effective remote learning strategies can be sustained and scaled to mitigate educational disadvantage both as pupils go back into school and during further disruption caused by future lockdowns. Not only is this a necessity but teachers and parents are desperate for evidence-based guidelines and strategies to support effective practices in the current crisis and for post-pandemic schooling.

The rapid pivot to remote learning in March 2020 created particular problems for teachers trying to support SEND students in mainstream schools. 73% of SENDCos reported that they experienced challenges including supporting SEND students remotely and supporting teachers to provide differentiated learning [33]. However, there is some evidence that SEND students found remote learning to be beneficial. For example, school leaders reported that students with autism and hearing impairments found it easier to study at home without so many distractions [34]. Furthermore, SEND students benefited from working at their own pace and being able to revisit and review learning activities [35].

4.4 Developing Inclusive (Digital) Pedagogies and Future Directions

Recent searches of the literature suggest an emerging trend towards encouraging and supporting teachers to develop inclusive pedagogies. These include examples by Moriña [36] who carried out a systematic review of approaches to inclusive pedagogies; Pozo-Armentia et al. [37] who explored pedagogical limitations to inclusive education and books aimed at teachers such as the recent edition, 'Inclusive Teaching in a Nutshell. A visual guide for busy teachers' [38].

In addition, a growing number of resources are available, such as the principles of Universal Design for Learning (UDL) (http://www.cast.org/our-work/about-udl.html#.XIZNwqbnW6k); Universal Instructional Design (UID); and resources provided by organisations such as CALL Scotland to enable disabled children to be supported by inclusive digital pedagogies (https://www.callscotland.org.uk/home/).

Universal Design for Learning is a design framework that is intended to ensure that teaching and learning is flexible and accommodates the needs of a diverse range of learners [39]. It does this through guiding teachers to develop inclusive pedagogy that represents knowledge in multiple ways, enables learners to express what they know in multiple ways, and maximises student engagement (e.g. through offering choice) [39]. Very little high quality empirical research has been conducted to date but there is a growing body of work that highlights its promise for making teaching and learning more inclusive and accessible [40–42]. The framework has not always been studied holistically with more studies focused on multiple representation of knowledge than multiple ways of students evidencing their learning [40]. Technology is often used to support a UDL approach as it lends itself to multimodal presentation, flexibility and adaptability [42, 43]. Evidence of the impact on attainment to date is mixed but some suggest that UDL can have a positive impact [41] whilst others claim there is, as yet, insufficient evidence [44]. Irrespective of this, of course teachers require professional development and time to develop new skills [40–43], whilst collaborative approaches to developing UDL resources and approaches can be beneficial [41].

In terms of inclusive education policy, enactment has been impeded in the past due to the inability to incorporate inclusion in competing political agendas [45]. Thus, more joining up is required to ensure that inclusive education is addressed consistently across all relevant policies. Future policies for inclusive education need to focus on funding, teacher education, establishing a repository of supporting information for practitioners and unlocking the potential of UDL-informed digital pedagogy to support inclusive education [28, 30]. This includes future policies that should pay attention to technology-enabled assessment which currently is often not informed by UDL principles and requires more research to ensure that access is equitable [30, 46]. To summarise, research and development in the coming years needs to enable disabled children to realise digital practices in inclusive ways within every aspect of learning and assessment within and outside of schools. In addition, on the ground, research is urgently needed to understand, capitalise on and maintain pandemic related benefits for teachers and for all children including disabled children in terms of knowledge and skills that have developed via the shift to emergency online learning.

5 Developing Fully Inclusive Digital Pedagogies

With this in mind, we report here on early findings from a participatory pilot project carried out in the North West of England, designed to engage class teachers and other key personnel who support disabled children in mainstream education to identify, assess and develop inclusive digital pedagogies. The project aims to identify the key factors at different levels that support class teachers to develop inclusive digital pedagogies; collect exemplars of good practice (4–5); and understand the current success factors and challenges faced by classroom teachers in developing inclusive digital pedagogies. Participants will identify exemplary inclusive digital use practices alongside those that require further development. Stages planned are: a summary review of previous studies drafted in relation to the principles of Universal Design for Learning; a workshop held with practitioners in each school to co-construct a framework for shaping understanding of how inclusive digital pedagogies can be recognised; a two-day visit to each school to identify and document practices at different levels of maturity in the use of inclusive digital pedagogies; thematical analysis [47] drawing on the framework developed in stage 2; a final workshop at each school to review the analysed data with experienced practitioners to ensure the participatory approach is integrated throughout the project. Draft reports will also be shared with the schools and final feedback from participants in the project incorporated before finalising. Ethical approval will be obtained through Lancaster University's rigorous and mandatory ethical approval process.

The project was originally planned for 2020, delayed until Summer term 2021, because of COVID-19. This meant that results; and the guidance the project will provide will take account of the re-entry point of teachers and children in England into schools. Two schools were recruited on the basis of externally recognised reputations for supporting disabled children. However, the ongoing impact of the pandemic on schools during Summer term 2021, including further lockdowns, resulted in data collection in one school only. Two group interviews were carried out using MS Teams with 2 teachers (a Mathematics teacher, also a digital learning leader; and a Science Teacher) and 2 support personnel for disabled children who work in the same school and described themselves as the 'Physical and sensory lead for children'; and a 'teacher of deaf children'). Questions focused on support for disabled children provided by the school pre-pandemic, during the lockdowns, with re-entry into schools, both generally and using digital technologies. Interviews lasted one hour. We have drawn on the data to provide examples of key challenges faced by teachers and support personnel during the pandemic and what this highlights in relation to inclusive digital pedagogies.

Providing student access to appropriate technology was a major challenge in this school. It took some time (beyond the first lockdown period) to provide laptops or iPads to SEND students. The school initially gave some students old laptops from in-house stock but they had a number of technical issues that needed to be resolved and the IT support staff were unable to respond quickly due to increased workload. In addition, not all students could access the live lessons. One of the main challenges that teachers reported were the difficulties of working with accessibility features in the standard software (e.g. Microsoft Teams, PowerPoint) adopted for remote teaching. Using live captions in Microsoft Teams to support hearing impaired students meant that teachers had to talk more slowly and annunciate carefully. Even then 100% accuracy was not achieved. Teachers partially addressed this by typing in further instructions through the chat facility, adding to their workload. Accuracy issues were also noted with the use of captions when pre-recording PowerPoint presentations. Standard software used to present curriculum content was also noted to be challenging to access for some students due to the lack of contrast and the colours used. The teachers pointed out that it was difficult for them to adapt their teaching resources due to the need to have a greater level of technical skill and confidence in using educational technology. Teaching assistants would have liked to provide simultaneous interpreting in Microsoft Teams for hearing impaired students but were unable to set this up, for example, as laptop cameras had been turned off. The teaching assistants also noted that some staff lacked understanding about some of their students' needs and were therefore unaware of pedagogic changes that could improve accessibility for some of these students. They also commented that sometimes teachers presented too much information simultaneously.

These early findings suggest the lack of readiness of teachers and schools to support disabled young people in the shift to remote learning in relation to students' access to laptops and tablet computers. This was amplified by time constraints for teachers combined with challenges to their pre-existing technical and accessibility skills. Moreover, teachers lacked the pedagogical knowledge needed to support these students' learning once teaching assistants were unable to provide their usual backup.

6 Conclusions

This paper has considered the different policies and perspectives that aim to ensure that disabled children's right to inclusive learning with digital technologies becomes a certainty. As noted earlier, we are at a fulcrum where teachers' and children's digital knowledge and skills have developed during the pandemic. We need to ensure that these shifts are maintained in order that the opportunities that they can provide are realised. On the other hand, historically, and as our early project findings show, the situation for disabled children's digital learning is not secure. Our project will continue working with teachers to identify, assess and develop inclusive digital pedagogies. However, we conclude by emphasising the urgent need for further research in this field to ensure that disabled children's rights to use digital technologies to support their learning in inclusive ways is recognised and supported.

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Students' Conceptions of Programming in the Context of Game Design

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Abstract. Several attempts have been made to understand novice programmers' difficulties and misconceptions in introductory programming. Most studies in the field of students' conceptions of (object-oriented) programming have only focused on identifying (mis-)conceptions without including popular contexts like game design. Since digital games are an important part of students' everyday life, exploring students' conceptions of digital games and their programming may give some recognisable patterns which might be helpful for teaching. This paper presents a brief overview of an empirical qualitative pilot study with the aim to investigate undergraduate students' conceptions of (object-oriented) programming in the context of the game Tetris®. For this study, we interviewed four students who were 19 to 21 years old, and analysed the transcripts using qualitative text analysis. Moreover, an online survey provided qualitative data from 25 participants. The first findings show that students' conceptions are based on the rules of the game, and first indications about influence factors could be found. As a result of these investigations, implications were made for the future main study.

Keywords: Conceptions · Computer science · Game design · Digital games · Programming · OOP · Qualitative text analysis

1 Introduction

Programming, especially object-oriented programming (OOP), is challenging for many students. Besides, many teenagers play digital games in their free time. Therefore, designing digital games in a computer science (CS) class could be a useful context in introductory programming. Unsurprisingly, designing and creating games is a common context to teach OOP or programming in general. By exploring students' conceptions of digital games and their programming with a long-term study, we want to get some insights into the development of conceptions in the introductory class and about possible influencing factors such as teaching materials, teacher instructions, or integrated development environments (IDEs). It has previously been observed that students especially develop misconceptions of object-oriented concepts [1]. CS teachers should be able to: identify and address students (mis-)conceptions for creating adequate learning arrangements. What is known about the investigation of students' perspectives is largely based on studies conducted in natural sciences [2]. Diethelm et al. [3] adapted

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the model of "Educational Reconstruction" for computer science education which emphasises that students' conceptions should be considered for course design and arrangement.

2 Theoretical Background and Related Work

2.1 Educational Reconstruction

Figure 1 provides the summary for the model of *Educational Reconstruction* adapted to computer science education (CSE) [3]. Nowadays, children are sur rounded by digital technologies (which can be defined as CS phenomena), "and at an early age, children start to form conceptions of how these technologies work and their basic capabilities" [4]. Therefore, students' perspectives have to be taken into account for designing courses equally to statements by the scientific community. Particularly, this model can be used for research in order to support CS teaching by exploring students' conceptions of various topics of CS. It is important to clarify that this model focuses on students' (pre-) conceptions rather than "mis"-conceptions, as this term already conveys that ideas might be wrong or invaluable.

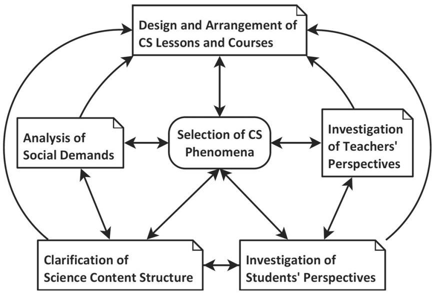

Fig. 1. Educational reconstruction for computer science education [3]

2.2 Students' Conceptions of Programming and OOP

Previous studies focused on different aspects of OOP concepts when investigating students' conceptions and mental models. For instance, Eckerdal et al. [4] describe a study of investigating students' conceptions of the OOP concepts *object and class* with a phenomenographic research approach. Other specific OOP topics were for example *objects* [5], *this operator* [6, 7], *storing objects* [8], *program state visualisations* [9], *primitive and object variables* [10]. In a literature review, Qian and Lehman [1] summarised "that students exhibit various misconceptions and other difficulties in syntactic knowledge, conceptual knowledge, and strategic knowledge." [1]. They have identified several impact factors on students' conceptions: "unfamiliarity of syntax, natural language, math knowledge, inaccurate mental models, lack of strategies, programming environments, and teachers' knowledge and instruction." [1]. Besides, Xinogalos, [11] lists numerous studies on novice programmers investigated, partially contradictory, conceptions of OOP [11]. In his study he found similar conceptions as in the study of Eckerdal et al. [4]. Most of the students had the conception of "'objects' as models/entities of some real-world phenomenon and 'classes' as models describing kinds of objects." [11]. A longitudinal study of the comprehension of OOP concepts by novices by Ragonis et al. [12] report that their results can be "divided into four primary categories: class vs. object, instantiation and constructors, simple vs. composed classes, and program flow" [12].

A much-debated question is how to survey students' conceptions properly [2]. Many studies used qualitative data as interviews and/or questionnaires with open-ended questions. Concept maps [13] and diagnostic tools [6] were also used to identify misconceptions. A literature analysis revealed few studies which surveyed high school students [7, 12, 14]. Most studies in the field have only focused on novice programmers in introductory courses at colleges or universities.

Up to now, no research has been found that surveyed students' conceptions of (object-oriented) programming in the context of digital games.

2.3 Game-Design in Computer Science Education

Thinking about creating games means thinking about objects and how they react to one another and to the player's input. So the game creator naturally thinks in an object-oriented way [15].

It has been demonstrated that various reasons such as motivation, interest or reference to students' everyday life are given for using a game-based approach in teaching. For instance, Rais et al. [16] say that a game-based approach supports students' understanding of object-oriented concepts. Even games (e.g. in [17]) with the content of object-oriented concepts were developed for an introductory CS course. Xinogalos et al. [18] emphasise the importance of engaging students in introductory programming by connecting the contexts to "their interest, such as games and mobile apps" [18]. In "Does Computer Game Design and Programming Benefit Children?" Denner et al. [19] analysed over 400 articles with the result that "computer game design and programming can lead to changes in programming knowledge, problem solving, and computer science attitudes and confidence." [19]. In another study conducted by Troiano et al. [20], it was shown that the game genre supports students' development of computational thinking skills. Besides, it helps students to focus on game design. Moreover, the researchers indicate to consider the impact of game genre while teaching programming with a game-based approach. To conclude this section, the literature identifies the lack of research in students' conceptions of designing and programming games.

2.4 Research Questions

The model of Educational Reconstruction suggests that successful CS courses should be designed by considering students' perspectives, and that game-based approaches in CSE are relevant for teaching introductory programming. Therefore, the research questions in this study focus on programming (OOP) conceptions of novice programmers in the context of digital games. Interviews will be conducted at several different points during a programming introductory course. The long-term investigation of students' developed conceptions may will also give insight into possible influencing factors. In particular, this study will examine the following main research question:

Which conceptions do students develop in different phases of introductory programming when learning OOP in the context of game design? The research question is divided into:

– Which conceptions do learners have about digital games and their functions?
– Which programming-related conceptions do learners develop about digital games and their functions and about (relevant) object-oriented concepts?
– How do programming environments/teacher instructions/materials influence students' conceptions of OOP?
– How does previous knowledge of programming/algorithms influence students' conceptions of OOP?

3 Study Design

The use of qualitative case studies is a well-established approach to investigate students' conceptions [2] and is a main part of the Educational Reconstruction for CSE (see Sect. 2.1). This investigation uses longitudinal data from semi-structured interviews to explore possible influence factors on students' conceptions. The semi-structured approach was chosen in order to compare the data of each individual and among each other. Furthermore, a questionnaire with open-ended questions generates qualitative data in addition to the interviews. The study uses qualitative analysis by using the method of Kuckartz [21] in order to gain insights into categorised conceptions.

3.1 Pilot Study

The pilot study was conducted in order to test the method and the developed instruments for investigation of students' perspectives. Particularly, it was important to check if the questions were chosen adequately. For the pilot study, the game Tetris® was chosen because it is well-known[1], has simple rules and a 2D game structure. Therefore, programming Tetris® could be a suitable task for undergraduate students. By surveying in two phases at the beginning and at the end of a course, the development of students' conceptions was conducted. This paper presents the results of the first surveys. The research questions were specified for the pilot study as follows:

– Which associations of the term "programming" do novice programmers have?
– Which conceptions of Tetris® do novice programmers have?
– Which conceptions of (object-oriented) programming do novice programmers have about Tetris® as an example for a digital game?

[1] "one of the best-selling video game franchises of all time" [https://en.wikipedia.org/wiki/Tetris].

Data Collection. The data was gathered via an online questionnaire, and interviews using an online video conference tool. It was carried out with an introductory course of Media Informatics at a college in Germany, in November 2020.[2] In total, four interviews and 25 questionnaires (19 filled-in completely) were used for the analysis. 49% (14) of the students were male, 41% (12) female, and 10% (3) made no indication of gender. Almost half of the participants had no previous school experience in the field of computer science. Several limitations to this pilot study need to be acknowledged. The sample size is small, probably due to excessive demand in the first semester and COVID-19 pandemic. Only online observations of exercises were possible due to the pandemic and distance teaching. The interviews were conducted with a video conference tool, where social interactions were limited.

4 Evaluation

The structured **questionnaire** has four parts: (1) general personal questions (age, gender, prior experience in computer science education), (2) open-ended questions "What do you associate with the term 'programming'?", (3) open- ended questions "How would you program this game? Please describe a possible approach by drawing or writing your ideas." and (4) questions about gaming in everyday life, and self-evaluation in programming skills and digital media usage. The **interviews** were semi-structured with a prepared guideline[3]. For the evaluation of the four interviews, we used the qualitative text analysis of Kuckartz [21]. By applying the first two steps, the interviews have the following main logical categories:

1. Concept of the term "programming"
2. Explanation of the game Tetris®
3. Explanation of elements in the game Tetris®
4. How to program Tetris®
5. Main game situations in Tetris®
6. Add-ons for Tetris®
7. References to the course contents
8. General personal information

Within the questionnaire and the interview, the students had the option to play[4] Tetris® for several minutes.

The following evaluation shows selected results of the qualitative text analysis. All the analyses were carried out using the software MAXQDA 2020. It is important to mention that some sections were coded twice.

[2] The course OOP 1 (based on *objects-later*) has started in October 2020, so the students have attended the course already for 3–4 weeks.

[3] See Appendix A.

[4] https://save-society.org/browser-game/tetris/.

4.1 Associations of the Term *Programming*

In Fig. 2, to the question “What do you associate with ‘programming’?” overall 26 [4 interviewed and 22 surveyed students] responses are grouped into 82 categories. This means that the responses were very diverse. About a third of the respondents stated “to code”, “programs” and/or “programming languages”. Generally, the responses may be divided into following four aspects: **close to everyday life** (e.g. “games, smart home, robots, future”), **application-oriented** (e.g. “websites, apps, server, systems”), **technical view** (e.g. “loops, variables, functions, Java, C#”) and **focus on planning—processes** (e.g. “pair programming, planning, testing, functional specifications, requirement specifications”). Interestingly, in only four answers we could find the term “object-oriented programming”. All of them, can be classified with **technical view**. No more analyses are feasible due to incomplete details of prior experiences in computer science education.

4.2 Conceptions of Game Design

The overall response to the online questionnaire was poor. There were 18 responses to the question, “How would you program this game? Please describe a possible approach by drawing or writing your ideas.” In contrast, the four interviewees responded their ideas extensively.

Table 1 illustrates the proportion of categories found. Almost 30% of those surveyed indicated that they do not have any idea. The themes of the **process** of designing Tetris and **implementing** of Tetris® recurred throughout the dataset. Some subcategories could be found in **implementing**: statements related to programming (**programming oriented**), the **bricks** and other **elements** of Tetris®. Several responses indicate conditionals, while explaining the design of the game execution. Just two participants used terms of OOP for their explanation. Furthermore, most of the statements were made from a *user's view* rather than *developer's view*. Overall, these results indicate that the majority of the students explained Tetris® by using their gaming experiences. It is therefore possible that the participants had almost no ideas of designing and/or programming a game before asking them. This result may be explained by the fact that at least 60% of those who were surveyed indicated not having any CS experience.

Fig. 2. Tag cloud of found categories of the term "programming" [N = 26]

4.3 Conceptions of the Game Tetris®

For the following analyses, we used the four interviews. Table 2 lists some details of interviewees, such as age, gender and former CS experience[5]. Altogether, three identified categories *bricks*, *game execution* and *anthropomorphism of computers* are presented.

Bricks. First of all, three interviewees (A, B & D) stated that the *appearance* of the bricks should have been defined. For example, a brick is formed by smaller parts like *pixels* or *squares*. One participant commented: "How are the pixels arranged for the specific brick?" [A]. Other responses included: "One brick is built with small squares. So, I would first define a square." [D]. These two conceptions show the idea of composition and may reveal an implicit object-oriented way of thinking. A common view amongst interviewees was that the following features of a brick can be changed: its *orientation* by turning it, the *position* (motion to left or right) or the *speed* while moving top-down. As one interviewee put it: ". . . a brick moves constantly in the same speed except the user speeds it up with the arrow keys. . . " [D]. Interestingly, the same participant stated that as soon as a brick does not move any more, it has reached the bottom and no more changes of that specific brick are possible. This statement may indicate the object-oriented concepts of *object* and/or *message passing* [22]. In one case, the participant B said that the game should also know "how many bricks to use and that bricks do not overlap" [B]. This may indicate the conception of a *defined number* of bricks and the characterisation of a brick with *constraints*.

[5] In the following text the quoted person is written in square brackets after the quotation.

Table 1. Conceptions of designing the game Tetris®: categories and examples (loosely translated from German) [N = 22]

Cat.	Subcategory	Example	Total
process	design	"…set the UI and the constructionby drawing up a mock-up…" [P21]	13
	planning	"…thinking about the elements and the requirements…" [P7]	9
	investigation	"…to get information about tools online…" [C]	5
	cooperation	"…by asking others for help…" [P19]	3
implementing – programming oriented	conditionals	"…delete a row, when its full…" [P13]	9
	algorithm	"calculating the score" [P13]	8
	testing	"generating automated tests" [P21]	3
	language	"… it depends on the selected programming language and its library…" [A]	2
	OOP	"… in a class diagram…required methodsand variables…" [P7]	2
	complexity	"…easy to run by the computer because no complex 3D models…" [A]	2
implementing – bricks	creating bricks	"…defining shapes for the bricks…" [P24]	9
	navigation	"…process player inputs (cursor keys) to move the bricks." [P24]	9
	random generator	"Select next object randomly…" [P8]	5
	speed	"define the speed of the bricks while moving" [P24]	3
	bricks in motion	"…the bricks should move from top to bottom…" [D]	5
implementing – elements	grid	"some kind of a table to use as the game field" [P23]	6
	scores	"…high score should be saved…" [P7]	6
	scoreline	"…scoreline increases when getting more scores" [P1]	3

Table 2. Details of interviewees

	Age	Gender	CS experience
A	19	m	5 years CS at school
B	21	f	1 year CS at school and some YouTube learning videos
C	20	f	no CS at school, but tried to learn coding with an online course
D	21	f	no CS at school, no experience

Game Execution. A variety of perspectives were expressed to describe different game situations. For example, one interviewee said: "… every pixel needs to be diminished with a specific value as it moves down on the y-axis." [A]. This view reveals the idea of the game field corresponding with bricks. Talking about this issue, another interviewee said: ". . . control if a row is occupied with bricks, then you can disappear [delete the bricks]." [D] Furthermore, the same participant thought that the bricks move nonstop top-down "without the opportunity of stopping them because otherwise the game would never end" [D]. In a similar way, another student said: ". . . there is a 'main-loop' for execution of everything . . . or for checking the user inputs. . . " [A]. In all cases, the students reported different game procedures by using *conditionals* which indicates concepts of *imperative programming*. As one interviewee said: ". . . *if* the bricks are outside the field, *then* the game is over." [C]. Another interviewee, when asked about the end of the game, explained: ". . . the game recognises, that the border is reached, so it does not run anymore" [B].

Anthropomorphism of Computers. In all cases, the students assigned human characterisations to the computer: "the computer needs to record" [A], "the game identifies" [B], "the program should know" [C], "the program sees" [D] or "the computer needs to know" [D]. In one case, phrasing the questions with personification of the computer "Do you have an idea, which information the computer needs to move [the bricks] to the left or right?" helped to evoke the student's conceptions: "He definitely would need the number of the fields and if they are unoccupied. . . " [D].

5 Discussion

While surveying the students about programming Tetris®, we recognised that the responses have been shallow. By asking the interviewees about specific game situations, e.g. "What is happening while a brick is falling down?", conceptions of game execution could be revealed in more detail. To summarise, these results show that students' conceptions are based on the rules of the game. One interesting finding is, when asked about possible add-ons for Tetris®, all of the students thought about *special bricks* which act as a *bomb* like in *Candy Crush Saga*. Overall, these results indicate that the investigated conceptions are very specific to the game Tetris®. Therefore, these findings are rather difficult to interpret as general conceptions for digital games, even though some of them could be adapted, e.g. "main loop" [A], to other digital games. Unsurprisingly, student A with prior knowledge in programming showed more concrete conceptions. Perhaps, the students will develop more conceptions about digital games by gaining more programming experience.

6 Conclusion and Further Work

First results of the pilot study show insights into students' conceptions of game design in the example of Tetris®. Furthermore, the current study found that students possess implicit imperative programming and object-oriented concepts. However, the exploration of students' conceptions of programming by using a game-based approach showed some weak points, e.g. conceptions based on specific characteristics of Tetris®.

The use of the open-ended questionnaire was not meaningful for our research goal. Therefore, we will focus on interviews in the main study.

After interviewing the students at the end of the introductory class, the evaluation will be consolidated. It is expected that object-oriented concepts will have a stronger influence. By finalising the evaluation of the pilot study, the interview guidelines will be optimised for the main study. In particular, we will add explicit questions about digital games in general, and will use Tetris® as an example and not as the focus of the interviews. In the main study, high school students will be interviewed at least three times (at the start, in the middle and at the end of the course) during the introductory class with the aim of getting more detailed conceptions related to object-oriented programming in the context of game design.

A Interview Guideline

The questions of part I will be asked on the different survey dates recurrently, whereas part II will be asked just the first time.

Part I - Game Design:

1. What do you associate with the term "programming"?
2. Play the game *Tetris®*.
3. Do you know this game? How would you explain it to a friend? What is the goal of the game?
4. How would you describe the different parts of the game? Which function could they have?
5. How would you program this game? Please describe a possible approach by drawing or writing your ideas.
   - Which function could have the playing field?
   - How could the controls work?
   - How does the game start or end? Can you describe it in detail?
6. Additional: Which expansion could you imagine for this game? How could you implement it/them?
7. Later on: Which topics of the class have caused the change of your conception(s)/ idea(s)? Was there anything in particular that helped you construct this new understanding?
8. What features and content of the learning materials presented in the class did you find beneficial to your understandings of programming concepts? How did it (they) help your learning experience?
9. So far, how would you evaluate your programming skills? Choose a number between 0 for very low and 10 for very high.

Part II - Individual Background:

1. Do you play digital games in your free time? If yes, how often and with which devices?
2. Do you have any experience in programming? Have you ever had any CS classes or programming courses?

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A Closer Look at and Confirmation of the General and Study Interests of Future Computer Science Students

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Abstract. Many factors can indicate pupils' tendencies to be interested in specific fields of study in the future. Examples of such measures are personal interests, which can also evaluate and develop institutional programmes and interventions that can support pupils' education in computer science. In this work, we report on a study to document characteristic profiles in general interests and study interests, surveying pupil cohorts that attend different activities related to computer science: workshops (compulsory and non-compulsory) and contests related to computer science. We match these interest profiles with the interests of first-semester students of computer science. Pupils attending computer science activities in their leisure time show similar or higher interests in study fields related to studying computer science than the students, differentiating them from pupils attending compulsory workshops. We also show that the relations between general interests and study interests are uniform for pupils and students, helping teachers and syllabus builders promote encouragement towards the interest in computer science.

Keywords: Interests · K-12 education · STEM · Student acquisition

1 Introduction

At the beginning of 2018, the European Union (EU) Commission presented the Digital Education Action Plan [1] and outlined how the EU intends to support educational institutions and education systems regarding digital transformation. According to the EU, the development of relevant digital competences is urgently needed in the age of rapid digital change, both professionally and privately. The Digital Education Action Plan focuses on the use of digital and innovative education practices and has three priorities: (a) making better use of digital technologies for teaching and learning, (b) developing relevant digital competences and skills for the digital transformation, and (c) improving education through better data analysis and foresight. The plan is also linked to the hope of getting more young people interested in technology and, ideally, inspiring them with a degree in, for example, computer science.

A lot of initiatives were started world-wide, by the EU and the European Countries. Also, at our university and department, we are trying to improve the situation at schools and universities by improving teaching quality [2, 3] and by providing motivating

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(gamely, inspiring) units of computer science and digital competencies [4] to pupils of different age groups. However, the critical question always remains: how sustainable are our interventions and programmes, and can we thereby create enthusiasm for technology and computer science among our young learners? Our long-term goal is to survey the sustainability to improve the quality and effects of our interventions.

To achieve that it is essential to know what characteristics are present in the pupils' target group, if and how these characteristics can be influenced, and what the 'ideal' characteristic for our goal is. This paper focuses on surveying specific interests that are present in pupil and student cohorts[1] to be used as a basis for further research.

The data that is collected in schools is often limited to the pupils' achievement in certain subjects or topics (mapped to grades). This is continued at university. But achievement (experienced success and failure) is not the only factor that is relevant to pupil's interests and motivation, and we can observe that (a) the achievement may be influenced by the academic self-concept of the pupils or vice versa [5], (b) high achievement does not indicate high interest in the subject, and (c) the personality influences the interest (also in certain kinds of tasks and therefore certain subjects) [6]. Therefore, when trying to motivate students, we should consider additional variables like self-concept, interest and personality, and not only their achievements. When measuring these variables, we can gain more information about the students we want to motivate, to see what differs pupils that claim to be interested in computer science or not, and, in the best case, we are also equipped with a way to measure the effect of our classroom interventions to show that they are working as they should. With the help of a survey tool for long-term studies (that is also compliant with the basic data protection regulations of the EU), we can learn more about the characteristic traits of pupils. Results on the gender differences in *personality*, *interests* and *self-concept* in the pupils' results have already been shown [7].

The objective of this paper is now to describe the interest profiles of pupil cohorts attending different CS-related activities (compulsory and recreational CS workshops, CS-related contests) and to compare these profiles to first-semester CS students' interests to confirm findings in literature and present (site-specific) new findings. So, this paper focuses on pupils with (and without) a high interest in CS and CS students. Future work will also compare students with (and without) interest in CS.

2 Related Work

There are many factors that influence the personal achievement and the success in school, at university and the working environment. PISA studies show that pupils are interested in science and technology until the age of 10 [8] but education in school is not able to convey a positive image of technology [9].

[1] In this paper we refer to school students as "pupils" and to university students as "students" to clearly distinguish the cohorts.

Curricula, school activities and school material could be designed in a way to strengthen (or raise) interest of pupils during their schooldays and encourage them to choose a STEM study. There are many (local) initiatives that try to fill this gap but they are often not surveyed scientifically [10]. Our framework can be used to survey the effects of interventions long-term and determine which interventions cause which effects on the interests.

Vocational interests (as defined by Holland [11]) are a known characteristic for many future life predictions, for instance educational choices and choice of work fields. Holland describes six areas of interest: *Realistic*, *Investigative*, *Artistic*, *Social*, *Enterprising* and *Conventional* (RIASEC). The fitting of the interest profile and the type of the (work) environment are important for the work satisfaction. These interests should not only be taken into account when evaluating work satisfaction: they can also be used in advance when choosing the field of study. In this work, we denote the vocational interests with the term **general interests**.

Some interests tend to be more stable than others over time: A three-cohort study with pupils of grades 7 to 12 indicates a more stable specification on interests in the areas denoted as *Investigative*, *Artistic*, *Enterprise* and *Prestige*. Older students have a higher interest in the areas *Realistic*, *Artistic*, *Enterprise* and *Conventional*. But the profile pattern of the interest showed stability over time [12]. A study of university students showed that increased scores in the interest *Investigative* increases the likelihood of the selection of a STEM study. Higher interests in *Artistic* and *Enterprising* decreased the likelihood. Males are generally more likely to choose a STEM study, especially if they have low scores in Social personality [13].

A study of pupils showed that high results on *Investigative*, *Artistic*, or *Enterprising* interests result in higher educational tracks than students that have high results in *Realistic*, *Social*, or *Conventional* interests. An explanation might be that pupils with a high interest in *Investigative* choose jobs in a higher social status because there they can pursue their interests [14].

When observing gender differences in the interests, girls have more interest in *Artistic* and *Social*: boys have more interest in *Realistic*. Regarding the STEM fields, the greatest difference in interests can be found in technology and engineering where boys are more interested. The same study observed the correlations between RIASEC interests and STEM interests, that were all positive [15].

Literature shows that there are interest profiles that advantage or disadvantage the future choice of a STEM study. We want to observe similarities and differences in these profiles of pupils and computer science students. So, we can identify if pupils currently interested in STEM activities have certain profiles, and if these profiles fit the profiles of computer science students. In this work, we chose to divide the cohorts only by age (pupils and students). The cohort of pupils is additionally divided by their STEM-related activity. We chose not to divide the cohorts by gender, which is a study focus in the future. Results for pupils divided by gender can already be found in [7].

3 Methodology

3.1 Research Objective

Our long-term objective is to learn more about key characteristics of pupils with (and without) a high interest in computer science. By using a test instrument supporting long-term studies, we set ourselves two goals, namely:

1. to demonstrate that (with our measuring framework) there are assessable differences between different pupil cohorts (pupils attending compulsory school workshops, non-compulsory recreational workshops and contests), and
2. compare these pupils' profiles with the results of first semester computer science students.

In this work, we report on differences in **general interests** [11, 16] and future **study interests**. We will use these results to investigate if and how relevant characteristics can be fostered and developed by classroom interventions in further studies.

To address the first goal, we investigate three questions. First, we investigate differences in the characteristics of different cohorts of pupils, to form a baseline of pupils' profiles regarding general interests and study interests. For this, we look closer at the following question:

- Q1: What are the differences between pupils who attend compulsory computer science workshops in their daily school life, and pupils who attend recreational workshops or contests related to computer science?

Second, we investigate if there are differences between the pupil cohorts and first semester students of computer science, with the assumption that interests of computer science students could be target interests when fostering pupils. Thus, our next question is:

- Q2: Are there measurable differences between the pupil cohorts' interests and interests of computer science students?

Third, aside from differences between cohorts, we investigate the relation between **general interests** and **study interests** in all cohorts. This way, we shed light on the cohorts from an inter-cohort and intra-cohort perspective. Our final question is:

- Q3: What is the relation between **general interests** and **study interests** in all cohorts?

We answer these questions by comparing responses to a long-term survey of personality, interests, and self-concept (Sect. 3.2) of different cohorts (Sect. 3.3). We compare mean values and confidence intervals and report correlations between **general interests** and **study interests** to detect differences and form profiles.

3.2 KAUA – Data Collection Framework

In this section, we briefly introduce the data collection framework used to survey the cohorts. KAUA (Košice and Alpen-Adria University Assessment) is an online survey system that was designed and implemented with the General Data Protection Regulation of the European Union[2] in mind. The framework contains a hashing service which converts personal data to unique ids, enabling anonymous longitudinal studies.

Table 1. Dimensions and items collected by KAUA [7]

Dimension	Items	Scale
General interests [11, 16]	Realistic, investigative, artistic, social, enterprising, conventional	9-level Likert [−4, 4]
Personality [6, 17]	Dominant/easygoing formal/informal	13-level Likert [−6, 6]
Self-concept [18]	3x verbal self-concept 3x mathematical self-concept	4-level [1, 4]
CS interest [7]	Computer science interest	6-level [1, 6]
Study interests [7]	History, art, music, literature, language, economy, law, social fields, health, natural sciences, informatics (CS), math, engineering, none	Yes/no [0, 1]

The data collection framework has already been used in studies [7, 19], and is explained in detail in [7]. In this work, we report on the first study that includes (undergraduate) students. Table 1 summarises the items included in the surveys:

- **General Interests**: Six dimensions of general interests following Holland (RIASEC) [11, 16]
- **Personality**: Two dimensions (Dominant/Easygoing, Formal/Informal) of the Five-Factor and Stress Theory [6, 17]
- **Self-Concept**: Verbal and mathematical self-concept, with formulations used in PISA surveys [18]
- **CS Interest**: Interest in Computer Science specifically [7]
- **Study Interests**: Interest in specific fields of study (now or in future) [7]

The purpose of the framework is to accompany pupils and students in their education. This includes specifically set activities and interventions that are great opportunities for informal learning. Such activities are popular but often not adequately accompanied scientifically [10].

3.3 Pupil and Student Cohorts

We have collected the following cohorts with the KAUA data collection framework:

- Participants of compulsory computer science workshops of years 2018–2020, organised by the Department of Informatics Didactics of the University of

[2] http://data.europa.eu/eli/reg/2016/679/2016-05-04.

Klagenfurt and attended by whole school classes, comprise the cohort `School` (n = 855, mean age = 13.97 ± 0.34).

- Participants of recreational computer science workshops of years 2018–2020, organised by the Department of Informatics Didactics of the University of Klagenfurt in Austria and attended by interested individual pupils, comprise the cohort `Recreational` (n = 104, age = 13.05 ± 0.53).
- Participants of computer science related contests: winners of the Austrian Bebras contest 2018 and participants of the School *Contest Catalysts Coding Contest* 2018 and 2019 comprise the cohort `Contest` (n = 90, age = 15.30 ± 0.73).

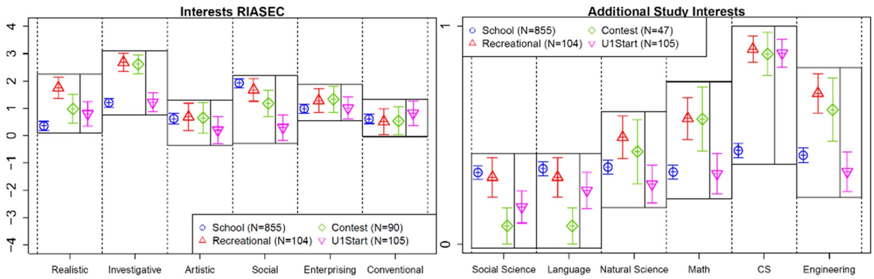

Fig. 1. Mean values and 95% confidence intervals of RIASEC and study interests of the cohorts

- First semester students of years 2018 and 2019, studying computer science at the University of Klagenfurt in Austria, comprise the cohort `U1Start` (n = 105, age = 24.54 ± 1.61).

All participants have attended a university or school in Austria. Note that a part of the cohort `Contest`, the investigated winners of the Austrian Bebras contest 2018 (n = 43), have been administered a former version of the survey, and have not been surveyed regarding their study interests. This leaves 47 participants in the cohort for those items.

4 Data Analysis

In this section we descriptively analyse and compare the responses of the described cohorts to the survey, focusing on general and study interests. We show mean values and 95% confidence intervals of the cohorts' survey responses in Fig. 1 and significant differences in Table 2.

4.1 Differences Between Pupil Cohorts [Q1]

First, we report on differences between the three cohorts `School`, `Recreational` and `Contest` regarding their **general interests** and **study interests**. Regarding the **general interests**, `School` pupils have a significantly lower *Investigative* interest than the other cohorts, and a significantly lower *Realistic* interest than `Recreational` pupils, but have a significantly higher *Social* interest compared to `Contest` pupils. There are no significant differences between the `Recreational` and `Contest` cohorts, although the latter features a lower mean in *Realistic* and *Social* interests. There are no significant differences for *Artistic*, *Enterprising* and *Conventional*.

For **study interests**, `School` pupils have a significantly lower interest in *Math*, *CS* and *Engineering* compared to both other cohorts. `School` pupils have a significantly lower interest in *Natural Science* compared to `Recreational` pupils, but have a significantly higher interest in *Social Science* and *Language* compared to `Contest` pupils. `Recreational` pupils have a higher interest in *Social Science* and *Language* compared to `Contest` pupils, but this difference is not significant.

Table 2. Significant differences, compared by mean values and 95% confidence intervals, between the cohorts regarding the collected items. The dimensions include, in order: general interests (gi), study interests (si). Superscript signs denote direction of the difference: lower (−) or higher (+) mean value for the row-cohort, compared to the column-cohort.

Q1	*Recreational (n=104)*	*Contest (n=90, n=47*)*
School (n=855)	(gi) Realistic$^-$, Investigative$^-$ (si) Natural Science$^-$, Math$^-$, CS$^-$, Engineering$^-$	(gi) Investigative$^-$, Social$^+$ (si*) Social Science$^+$, Language$^+$, Math$^-$, CS$^-$, Engineering$^-$
Recreational (n=104)		(si*) Social Science$^+$, Language$^+$

Q2	*U1Start (n=105)*
School (n=855)	(gi) Social$^+$, (si) Social Science$^+$, CS$^-$
Recreational (n=104)	(gi) Realistic$^+$, Investigative$^+$, Social$^+$ (si) Natural Science$^+$, Math$^+$, Engineering$^+$
Contest (n=90, n=47*)	(gi) Investigative$^+$, (si*) Math$^+$, Engineering$^+$

4.2 Differences Between Pupil Cohorts and AAU Students [Q2]

We next report differences between the pupil cohorts and first-semester computer science students at the University of Klagenfurt (`U1Start`). Regarding their **general interests**, `U1Start` students have a significantly lower interest in *Social* than both `School` and `Recreational` pupils, a significantly lower interest in *Realistic* than `Recreational` pupils, and also a significantly lower interest in *Investigative* than both `Recreational` and `Contest` pupils. Again, there are no significant differences for *Artistic*, *Enterprising* and *Conventional* interests.

Looking at the **study interests**, `U1Start` students have a significantly lower interest in *Social Sciences*, but a significantly higher interest in *CS* compared to `School` pupils. `U1Start` students have a similarly high interest in *CS* compared to both `Recreational` and `Contest` pupils, but have a significantly lower interest in *Natural Science* compared to `Recreational` pupils, and a significantly lower interest in *Math* and *Engineering* compared to both `Recreational` and `Contest` pupils. There are no significant differences for *Language* interests.

The students show a more differentiated interest in STEM fields: They have the highest interest in *Computer Science* (their field of study) and lower interest in *Natural Science*, *Math* and *Engineering*.

4.3 Correlations Between Interests [Q3]

We only report significant Spearman correlations ($p < .05$) with an absolute correlation value $\sigma \geq .20$ (indicating at least a weak correlation). We mark correlations with sufficient power with an asterisk, following a power test with $p < .05$, a power of $.95$, and the respective cohort size.

The correlations between **general interests** and **study interests** yield a uniform picture across the cohorts. There are no significant correlations for `Contest` pupils.

For non-technical **study interests** of the `School` cohort, the **general interest** *Artistic* is weak positively correlated to interest in *Social Science* ($\sigma = 0.21$*) and *Language* ($\sigma = 0.27$*). The **general interest** *Social* is weak positively correlated to interest in *Social Science* ($\sigma = 0.34$*).

In the `Recreational` cohort, *Language* is weak positively correlated to *Investigative*, *Artistic* and *Social* ($\sigma = \{0.21, 0.21, 0.22\}$), and *Social Science* is weak positively correlated to *Social* ($\sigma = 0.28$). The `U1Start` cohort shows positive correlations of *Social Science* to *Social* and *Enterprising* ($\sigma = \{0.44$*, $0.20\}$), and of *Language* to *Artistic* ($\sigma = 0.37$*).

Regarding technical **study interests**, the **general interest** *Realistic* is positively correlated to the interest in *Natural Science* (`Recreational`: $\sigma = 0.22$, `U1Start`: $\sigma = 0.31$), *CS* (`School`: $\sigma = 0.24$*) and *Engineering* (`School`: $\sigma = 0.40$*, `Recreational`: $\sigma = 0.27$, `U1Start`: $\sigma = 0.42$*). The **general interest** in *Artistic* is positively correlated to the **study interest** in *Natural Science* (`Recreational`: $\sigma = 0.26$), but negatively correlated to *Math* (`Recreational`: $\sigma = -0.31$) and *Engineering* (`Recreational`: $\sigma = -0.32$, `School`: $\sigma = -0.21$*).

The **general interest** in *Social* is weak negatively correlated to the **study interest** of *Natural Science* in the `U1Start` cohort ($\sigma = -0.23$), but weak positively correlated in the `School` cohort ($\sigma = 0.16$*). *Social* is weak negatively correlated to the interest in *Engineering* (`U1Start`: $\sigma = -0.20$). The **general interest** in *Enterprising* is weak negatively correlated to *Natural Science* (`U1Start`: $\sigma = -0.23$). The **general interest** in *Conventional* is weak positively correlated (only in the `Recreational` cohort) to **study interests** in *Math* ($\sigma = 0.25$) and *CS* ($\sigma = 0.21$), and (only in the `U1Start` cohort) weak negatively correlated to the interest in *Engineering* ($\sigma = -0.21$).

5 Discussion

In this section, we present a discussion and possible explanations for the differences of **general interests** and **study interests** of our cohorts. Many factors, such as sociocultural ones, have an influence on these interests and can be assessed in studies. But educators can hardly change them in their classroom settings. We therefore only assess factors that we believe to be *malleable*, such as **general interests** and **study interests**. Pupils' learning can also be influenced by their peer group (e.g., see [20]) but in our study we see learners as individuals and aim to provide a baseline of interest measures, assessing the effects of classroom interventions in the future.

5.1 Differences Between Pupil Cohorts [Q1]

With our first question (Q1) we were looking for the differences between pupils who only attend compulsory CS workshops (`School`), and pupils who attend recreational workshops (`Recreational`) or contests (`Contest`) related to CS.

`Recreational` pupils and `Contest` pupils show similarities in their interests. But these two cohorts show significant differences compared to the `School` pupils. So, pupils who attend computer science activities have a specific profile of interests. They can be distinguished from `School` pupils by these traits.

`Recreational` pupils and `Contest` pupils have a high **general interest** in the *Investigative* domain (a factor that is important for their choice of fields of study [13]). This is confirmed by their higher **study interests** in *Math*, *Computer Science*, and *Engineering*, compared to `School` pupils. This factor can also be seen as an essential factor for choosing to attend a computer science activity.

Given these differences in traits between pupils of compulsory computer science workshops and pupils who attend computer science activities, as a next step we plan to design workshops intended to influence the *Investigative* interest (and other traits) of pupils. With our framework, we can also survey changes of traits over time that will show us the effects of our interventions in the future.

5.2 Differences Between Pupil Cohorts and AAU Students [Q2]

With our second question (Q2) we wanted to know if there are measurable differences between pupils' characteristics and students' characteristics.

Pupils of recreational workshops and contests show higher **general interest** in the *Investigative* area, which plays an important role for the choice of fields of study and is thus in line with current research [13]. Surprisingly, the students do not show such a high *Investigative* interest. We assume that the study specialisation offered at this university has an influence on that factor.

`Recreational` pupils and `Contest` pupils as well as `U1Start` students show higher **study interest** in *Computer Science* compared to `School` pupils. The pupils attend these activities because of their interest in the subject, whereas pupils in school workshops have to attend them regardless of their interest. The higher interest is thus expected. The other two pupil cohorts have a similar interest in *Computer Science* compared to the students.

The `Recreational` pupils and `Contest` pupils show a higher interest in *Natural Science*, *Math*, and *Engineering* than the students. Possible explanations are that the students already chose their field of study and therefore rate their interest in this field (CS) highest, or that they have more insight into different fields of study and their respective characteristics which allows them to give a more differentiated rating.

5.3 Correlations Between Interests [Q3]

The *Artistic* interest is negatively correlated to some STEM studies (which is expected, see [13]), but not to *Natural Science*. It is possible that pupils have a different understanding of the fields of study of *Natural Science* compared to students (although the corresponding survey items account for different age groups). This could also be an explanation for the discrepancy observed between the pupils and students in the correlation of *Social* interest and *Natural Science*. The pupil cohorts show a positive correlation, the student cohort shows a negative correlation. There is no discrepancy on the correlations of the *Social* interest and the study interest *Engineering*: the correlation is negative in all cohorts.

The *Investigative* interest is positively correlated to all study interests of `School` pupils ([0.07, 0.16]). Although this interest is seen as a predictive factor for STEM studies, our data shows that this factor has a (small) effect on different fields of study. The *Realistic* interest shows only positive correlations to STEM interests.

The correlations between **general interest** and **study interest** confirm results presented in literature. But it also shows differences between the cohorts. The (future) study interests of pupils are always dependent on their current knowledge of the field. Pupils may have a different imagination of a certain field of study, compared to students who actively chose a study.

6 Threats to Validity

When comparing vocational and study interests of pupils and students, social and cultural backgrounds could have uncontrolled effects on the investigated characteristics. In this study, all participants originate from Austria, mitigating this threat.

Potential threats to validity arise from the survey that was used to collect the data. Although the pupils and students participated in the same survey, the wording of the survey items are different to fit them to the age group. This may have an influence on the results. Moreover, answers of self-assessments are dependent on the personal perception of the question - this may be different for pupils and students. Pupils may have a different preconception of specific fields of study due to their level of knowledge about the field.

Another source of threats to validity arises from the division of pupils into cohorts. The pupil cohorts are divided by the kind of computer science activity they participated in. Our assumption is that the pupils attending recreational workshops are specifically interested in STEM activities. This may not be true: they may be registered as their parents want them to attend. However, the results support our assumption. Also, the cohort of pupils attending compulsory workshops is a heterogeneous group, with pupils that are interested in a wide variety of additional activities. The correlation analysis reveals that all relations between the interests are uniform between the pupil cohorts. Therefore, the cohort of pupils attending compulsory workshops forms a control group of all pupils, while still containing pupils with specific characteristics.

Regarding internal validity, we report significant findings with $p < .05$, and report correlations following a power test with $p < .05$ and a power of $.95$.

7 Conclusion

In this paper, we show the use of a survey tool for gathering specific characteristics (general interests and study interests) of pupils that indicate future interest in computer science. We compare pupil cohorts attending compulsory CS workshops, recreational CS workshops, and CS contests, and first semester students of computer science. We demonstrate that there are differences in the profiles of interests between pupils attending compulsory and non-compulsory activities and student cohorts, and that there are uniform correlations between general interests and study interests.

It turned out that pupils of compulsory computer science workshops are significantly less investigative, and significantly less interested in numerous fields of study (Natural Science, Math, CS, Engineering) compared to pupils attending non-compulsory activities. This confirms the assumption that an Investigative interest is a possible influence on the choice of a STEM study.

Concerning the characteristics of first semester students, we learned that the study interest in CS was high, but the study interest in all other STEM fields (Natural Science, Math, Engineering) was lower than expected. Moreover, the interests in these STEM fields are lower compared to the pupil cohorts of non-compulsory activities. A possible explanation is that the pupils may have a broad interest in STEM and do not (or cannot) differentiate the characteristics of STEM fields, in contrast to the student cohort that already chose a study of their specific interest (and rejected the other choices).

Correlations between general interests and study interests show that the Investigative interest is very weak, but positively, correlated to all study interests, not only CS. An Artistic interest is negatively correlated to an interest in Engineering, making it a possible target of interventions to improve interest in STEM-related fields of study. Observed discrepancies between pupil and student cohorts (Social interest is positively correlated to Natural Science in the pupil cohort, but negatively correlated in the student cohort) can be attributed to different states of knowledge.

We demonstrate that it is possible to collect interest profiles of pupils' cohorts with our KAUA framework, and we confirm findings in literature that there are certain interests that influence the (future) choice of study in STEM-related fields (Artistic, Social, Enterprising). To improve enrollment in computer science and STEM-related fields, an avenue of future research is the design of interventions to convey holistic notions of those fields, attracting students who previously saw themselves as a bad fit.

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Starter Projects in Python Programming Classes

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Abstract. Starter projects are part of constructionist learning arrangements (1, 2). The term was mainly coined by the Scratch community and describes a simple, executable program that is designed to encourage copying, exploring and further development. This contribution first discusses three types: test programs, examples that illustrate programming techniques and algorithms, and architectural prototypes. It then presents self-observations of university students, describing how they use starter projects for learning.

Keywords: Starter project · Programming · Constructionism · Python

1 Introduction

1.1 Starter Projects

A starter project is an executable computer program that has been designed as learning material. Beginners copy, test and change the starter project, and develop it further according to their interests. The term starter project was coined and cultivated by the scratch community. There are collections of starter projects on various topics on the Scratch website. A well-known example is a minimal version of the video game Pong. The concept of the starter projects is based on the fundamental idea of constructionism [1, 2]: People learn best when they construct relevant (digital) artifacts and share them with others. The term "starter" expresses that a development process is being started. This can be seen both as an individual and as a collective process. From the individual perspective, the starter project is the starting point for a series of iterations in which the software is refined, expanded and improved. This roughly corresponds to the procedure for agile programming (e.g. Extreme Programming [3]). A collective development process happens, when remixing Scratch projects takes place: Somebody picks a Scratch project that she or he likes from the Scratch website and develops it further in the online editor. In this way, a tree of derived projects (remix tree) is created from a starter project. For example, there were more than 26,000 remixes of the just mentioned starter project Pong (February 2021).

1.2 Starter Projects and Tinkering

A constructionist concept connected to starter projects is tinkering. "The tinkering approach is characterised by a playful, experimental, iterative style of engagement, in

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which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities." [4, p. 164]. Resnick and Rosenbaum see spontaneous trying out and tinkering in contrast to instructional guidance in tutorials and detailed task descriptions that hinder an independent and self-controlled approach. They [5] point out that trying out also includes making mistakes and requires a "Failure-friendly way of thinking". However, failure is only helpful for learning if there is an opportunity to improve. The time frame of lessons is strict and children from socially disadvantaged backgrounds often do not have the opportunity to finish their projects at home [5]. A starter project makes it easier to start a tinkering process, and guarantees success because it already works. From the starter project, students can carefully find their (individual) ways into new areas, and try out unfamiliar programming concepts. The number and scope of the iterations can be determined by themselves. Which working environment do programming exercises with starter projects require? They [6] describe the general conditions for (physical) tinkering activities. Among other things, a seed, a playground (physical and organisational environment), tools and materials are needed.

Seed. The seed is the reason for starting the tinkering. This can be anything which arouses interest and motivates students to start. By definition, a starter project can be the seed of a software project.

Playground. The ambience of the room should support a playful attitude, cooperation and sharing results [7]. Terms such as Makerspace, Incubation Space or Fab Lab have been established for the architectural concept. Regarding the organisation, it is important that there is enough time for creating presentable products at every pace of work, and that there is opportunity to share results.

Tools. In programming projects, the primary tool is the development environment. In the case of Python programming, these are e.g. IDLE (Integrated Development and Learning Environment), which is included in the standard distribution, or other educational development environments such as Thonny and Geany.

Material. In a physical maker project, the materials that can be used are typically spread on a table. They invite participants to touch and try out. At the same time, they also represent a limitation or channeling, because the project can only be completed with the material offered, and with nothing else. In a programming exercise, the materials to create a digital artifact are the programming concepts used. A starter project can be a material in several ways. It explains and illustrates certain programming techniques, and it is also a model for good programming style (structuring, meaningful names, comments etc.). Sometimes, a collection of starter projects, each one illustrating a different technique, may be of help. Further materials that are brought in are language references, sheets with overviews ("cheat sheets"), skill cards, or posters on the walls.

2 Starter Projects and Examples

2.1 Types of Starter Projects

Principally, every computer program can be the starting point of a development, and can therefore be a starter project. However, in this paper it is assumed that a Starter Project has been designed specifically to encourage and facilitate learning. Regarding the intended learning activities one can roughly distinguish three types of starter projects: Test program, example, and architectural prototype.

Test Program. A test program is a small program with the primary function of demonstrating that the mechanics of program execution work. The classic example of a test program is a "Hello World program" that displays a short text like "Hello world" on the screen, and does nothing else. Probably the first Hello World program was published by Brian Kernighan in 1974 in a tutorial for the C programming language. The much-quoted original text reads.

```
main() {
        printf("hello,world");
}
```

Although the program text is very short, it contains some abstract concepts and is not easy to comprehend. In Python syntax the code is much simpler:

```
print("Hello world")
```

However, if this is the very first program that a person writes and runs on the computer, it is not expected that they understand the program constructs. When a student just writes the program in the editor, starts it, and looks at the output, he or she has not understood the print() function better. But this person, who has never done this before, gets confident that he or she can do it. Exploration and trying out is not targeting the program text itself but its digital environment: The integrated development environment (IDE) (write a program text, understand the syntax highlighting) the operating system (create a project folder, store, load and run a program) and the interpreter or compiler of the programming language (understand system messages).

Test programs may be more complex than a "Hello World" program. Figure 1 shows a screenshot from the run of a simple Python program showing the live image from a public webcam (webcam viewer). When you click the button, the image is updated. You can see the changes. The source code is truly short (17 lines of code). However, to understand it requires specific programming knowledge (e.g., about GUI programming and image processing). The program is not suitable for introducing new programming concepts, such as the definition of button widgets. That would be done with different (more specific) examples. The program is a test program if the purpose of running it is to get certainty that it works in the current environment.

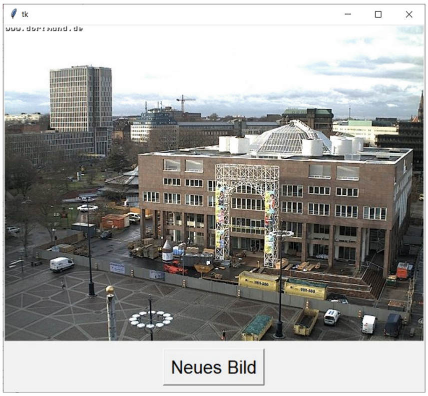

Fig. 1. Webcam-viewer

A test program like the webcam viewer can be used to initiate a creative task. Example: “Describe the idea for a Python project that evaluates live images from web cams and extracts meaningful information”. In case of the web cam image shown in Fig. 1, a possible project idea is: The program checks whether someone tries to climb over the site fence. (The program checks changes in colour from the pixels on the site fence.)

The advantage of a test program over simple verbal or visual descriptions is that it proves to beginners that an implementation of a project idea in this topic is within reach. They may not understand the program completely, but they see that a few lines of code suffice to implement a certain functionality.

Example Program. An example program illustrates a programming technique and thus combines a topic and programming concepts into a holistic unit. In contrast to a test program, the focus is on the program text – in terms of functionality and style. This Python project illustrates the Python string-method format() and how to use it in a storytelling project.

```
STORY = """ One Saturday morning {she} was walking down
the street with her {thing}. She thought, "How good that
I have the {thing} with me. " """
name = input("Female first name: ")
thing = input("A thing to carry around: ")
text = STORY.format(she=name, thing=thing)
print(text)
```

Example programs can initiate specific *learning* activities like experimenting with the code. Additionally, they can be designed to provoke different *creating* activities, including extending, improving, and transferring.

Extend: The starter project is a very basic program, which must be extended by adding functions. Example: The starter project manages a dictionary and allows nothing more than to look up the translation of a word. Possible extensions are to add new items and to store the updated dictionary.

Improve: The starter program has an extremely low performance. The challenge is to improve the quality of the output and/or the time complexity. E.g., consider a path-finding Python program with a dictionary representing a graph (mapping nodes to lists of adjacent nodes) and a simple recursive function:

```
from random import choice
G = {1: [2, 4], 2: [1, 3, 5], 3: [2, 5],
     4: [1, 5], 5: [4, 2, 3, 6], 6: [5]}

def search_path(node, goal):
    if node == goal:
        return [node]
    else:
        path = []
        while not goal in path:
           path = search_path(choice(G[node), goal)
        return [node] + path
```

The function works fine and returns a path from node to goal, if such exists. But the path may be not the shortest and may even contain loops. This is a sub-optimal result, and the program spends considerable unnecessary time.

Transfer: The starter project can represent functional pattern, which can be applied broadly. The Python program illustrating how to use string methods in a storytelling project can easily be transferred to different projects in a large variety of domains. Another widely applicable pattern is an interactive program, which first reads some data, then processes the data, and finally outputs the results. The creating process does not necessarily imply learning according to the teacher’s goals. Sometimes students invest much time for developing a project just by creating beautiful graphics, or adding data without changing the program’s structure. For example, in a grade 10 programming class students got a Python starter project, illustrating how to pick a random item from a list. When the user hits the ENTER key, the program prints a “motivating motto” on screen.

```
import random
mottos = ["You look great today!",
          "Never give up.",
          "Yes, you can do it!"]
while True:
    text = random.choice(mottos)
    print(text)
    input()
```

One group loved this project and developed a version, printing random “fun facts”. For several hours, they searched fun facts on the internet and created a very long list with dozens of items. This way they transferred the example program to a new domain and extended it, without learning much about programming.

Architectural Prototype. An architectural prototype is a program that is syntactically correct, but is functionally incomplete. The source text provides the architecture of a more complex project. An example is a graphical user interface with widgets for input and output and buttons that trigger actions when clicked. The function definitions are dummies that have no effect; e.g., in Python syntax:

```
def action():
    pass
```

Another example is a program with incomplete class definitions (attributes and dummy methods) illustrating an aggregate of classes modelling some real structure. An architectural prototype can help to cope with complexity by providing cognitive offload and channeling. When it is the starting point of an iterative development process, the students could start with filling the gaps, for instance by writing function definitions based on verbal specifications (pre- and post-conditions or test requirements). On the one hand, the architectural prototype – since it is already running – offers a test environment. You can start the program, and see from the output whether the self-defined function is working properly. On the other hand, the programming challenge (focusing on mere technical programming concepts) becomes part of a “real” project. Architectural prototypes are sometimes used for written exams because both analytical skills (explaining the program text) and constructive skills (formulating the program text) are tested.

2.2 Starter Projects and Worked Examples

Starter projects are comparable to worked examples in problem centred science education. A worked example is a prototype solution that guides the student through solving the problem, step by step [8]. Worked examples (in science, as well as in mathematics and informatics) are presented in different forms: e.g. in the classroom by a teacher, in explaining videos, in textbooks or animated tutorials [9]. When students solve science problems on their own, they tend to look for work they had recently elaborated in class, and try to adapt these for solving the new task [10]. The advantage of worked examples (compared to problem solving) is the reduction of cognitive load resulting from processes that do not contribute to learning (ineffective load). Like worked examples, starter projects are prototype solutions, and help to reduce cognitive load. They prevent learners from being overwhelmed by the number of information elements that need to be processed simultaneously, when they start a programming project from scratch. However, one can point out three major differences:

1. A starter project is processed actively and self-controlled, whereas a worked example includes guidance. Instead of following a given path, students explore the code in their own way and change it.
2. A starter project is designed to initiate learning activities and to challenge creativity. It encourages the students to apply certain programming techniques (covering the curriculum) by the given material. But the students can decide, themselves, about design goals. Tinkering with the code may lead to new design ideas, and consequently to research and implement activities that go beyond the scope of the original code of the starter project.
3. A starter project is supposed to be used immediately (and not eventually later like a worked example). It reduces cognitive load (that might act like a barrier) and motivates to start a development and learning process.

These three attributes of starter projects lead to the research questions of a survey, which is presented in the following section.

3 Self-observations on Learning with Starter Projects

This section presents self-observations of university students who have attended an introductory Python course. Two questionnaires were used at two different days covering these research questions:

1. How do students process the code of a starter project?
2. What kind of learning activities do students choose during the development initiated by a starter project?
3. What kind of creative design activities (improving, extending, transferring to a new context) students are interested in?

The University of Münster (Germany) has offered introductory Python programming courses for students of all faculties. The participants can achieve two different types of certificates: everyone who has attended the course regularly receives a certificate of participation without any grade. Students who have successfully passed a written exam at the end of the semester will receive a higher-ranked certificate with a grade. One can assume that at least the exam writers were – additionally to intrinsic motivation – extrinsically motivated to accomplish programming competence during the exercises. The lectures usually have taken place in a computer lab. Each lecture has lasted 180 min plus one 30-min-break. Beside presentations and discussions, a main part has been hands-on programming exercises based on different types of starter projects. In each hands-on session, the students could pick from a small repertoire of two or three tasks. In the winter semester 2020/21, this course took place in a digital form (Zoom meetings with breakout sessions for programming exercises). The students were asked to fill questionnaires related to these exercises. One question was whether they intended to take part in the written exam, but no further questions about the person (like age or gender) were asked. Primarily, the questionnaires should encourage students to reflect on their style of work, which was not seen as a part of a scientific study, but a regular part of the learning process.

3.1 Processing Starter Projects

The first questionnaire was filled by 29 students (group "all"), 12 of them intended to do the written examination (group "exam") 8 did not (group "no exam") and the remaining were still undecided. The exercises that day contained 5 tasks with starter projects (type "Example") the students should try out and change at will. On average, each student worked on 55% of the tasks. The students were asked to reflect on how they handled starter projects, and to check all statements that applied. Table 1 shows the results.

Table 1. Processing starter projects

Statement	All (N = 29)	Exam (N = 11)	No Exam (N = 8)
1: I typed program text and did not just copy it with drag and drop	15 (52%)	9 (82%)	2 (25%)
2: I have not copied program text literally but changed it immediately	11 (38%)	4 (36%)	4 (50%)
3: I have copied program text with drag and drop	9 (31%)	1 (9%)	4 (50%)
4: I have modified program text in order to explore the effects of instructions	19 (66%)	8 (73%)	7 (88%)
5: Only after I fully understood the program, I tried to implement my own ideas	10 (34%)	5 (45%)	1 (12%)

It is remarkable that many students (15 out of 29), and especially exam writers (9 out of 11), typed the program texts of the starter projects instead of copying them into the editor with drag and drop. Most students reported that they actively explored code by modifying it.

3.2 Initiated Learning Activities and Effects

Beside tinkering tasks, the exercises on that day included four problem-oriented tasks in the style of exam tasks. In these tasks, the challenge was to write a Python program according to a given verbal specification. Example: "Write an interactive program that calculates the volume of a pyramid." On average, each student worked on 53% of these tasks. The students were asked to reflect on their work, related to these problem-oriented tasks, and to check statements that applied. The same statements (partly with slightly different wording) were also given for the tinkering tasks with starter projects before. Table 2 compares the results regarding the two types of tasks. The results show that both problem-oriented tasks and tinkering tasks with starter projects initiated a considerable amount of learning activities, and a feeling of learning success (no significant differences with chi-square statistic on $p < .05$).

Table 2. Initiated learning activities and effects

Statement	Tinkering (N = 29)	Problem (N = 29)
6: I have made experiments in the Python Shell to explore the effects of instructions	22 (76%)	17 (59%)
7: I felt inspired to develop my own programming project	9 (31%)	9 (31%)
8: I looked in the course material or other sources for Python commands that I might need	17 (59%)	21 (72%)
9: I feel like I have learned something new while working on the task	23 (79%)	24 (83%)
10: I was proud of my result	6 (21%)	11 (38%)

3.3 Tinkering Versus Problem Solving

The students were asked to make an overall assessment of which type of task they preferred. The majority preferred solving problems over free tinkering (Table 3).

3.4 Motivation for Creative Development

On another day, the students got three different types of tasks with starter projects (type: example). They differed in their expectations about what way the given code should be developed. The students were asked to rate their motivation, to extend, improve or transfer starter projects. They had experienced examples of these three types, but they were asked to rate the task type and not the concrete example. The 18 respondents reported to be motivated by all three types of challenges with a median of 4 on a 1-5-Likert scale (1: not motivated, 5: highly motivated).

Table 3. Overall assessment of task types

Statement	All (N = 29)	Exam (N = 11)	No Exam (N = 8)
11: I prefer to tinker with a starter project	9 (31%)	3 (27%)	2 (25%)
12: I prefer to solve tasks with a problem specification	15 (52%)	7 (64%)	4 (50%)

4 Discussion

4.1 Active Writing

A perhaps surprising result of the first questionnaire is that students see writing (typing) rather than copying from the digital hand-out by drag and drop as an appropriate way to elaborate starter projects. Since they created individual versions of the code by changing and adding words, this can be seen as a special type of "writing to learn" like journal learning [11]. According to [11] the positive effect of journal writing can be increased by appropriate learning strategy prompts. Some successful prompts from journal learning could be adapted to exercises with starter project. An example of an elaborative prompt would be, "Add explaining comments to the program code." A metacognitive monitoring prompt is, "Indicate (by comments) the lines of code, you have problems to understand."

4.2 Desire for Challenge

The results of the survey suggest that many students are attracted by the challenge of problem-based tasks (including the risk of failure). To make exercises with starter projects more challenging, teachers could add specific prompts articulating expected goals of development (improve, extend, transfer). Examples for improve-prompts, "Make the program faster.", or "Improve the user interface."

4.3 Creativity

31% of the respondents of the first questionnaire reported to be inspired to create their own project. In the revised version of Bloom's taxonomy of educational objectives, "Create" is the top category [12] in the cognitive process dimension. Accordingly, one might say, that these 31% have high learning ambitions. Constructionism assumes that the wish to create something relevant is a strong motive for learning. However, in this specific context (at the beginning of a programming course), tinkering and exploring code (mainly corresponding to the process categories understand, apply and analyse) seem to be more important than implementing own ideas. According to Csikszentmihalyi, creativity is a social phenomenon and requires a "field" of experts who decide whether an artifact is a novelty within the domain. Learning arrangements with starter projects can get more challenging, if the students are explicitly asked to create something new and unexpected. To make the development a creative process according to Csikszentmihalyi's model [13], students must present their work to the "local field" of classmates who decide about its novelty in some way, for example by rating and commenting. To foster self-efficacy and creative confidence [14], the students should be made aware that there are many ways to add something to a starter project and that at least some of the possibilities are within their reach.

5 Conclusion

Starter projects are digital artifacts that are carefully designed by teachers and textbook authors. In contrast to worked examples (which have a long tradition in math and science education), students and book reader process these code examples in order to learn programming. Starter projects may explain concepts, but they also initiate further exploring activities. Participants of an introductory programming course at a university report, that they, at least at the beginning, prefer a "learning by writing" approach. Typing code beats copying it by drag and drop. It seems to be important to embed starter projects in an "educational environment" that supports tinkering (by offering additional material and support) and is challenging. Starter projects could be enriched by learning strategy prompts, and creativity challenging prompts.

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National Policies and Plans for Digital Competence

Computer Education in Australia Fifty Years Ago

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Abstract. This paper is about computer education in Australia fifty years ago when it was just at its beginning. It makes particular reference to the State of Victoria. The paper covers the period of the 1950s–1980s. It looks at how, after the first mainframe computers appeared, university courses in programming began in the 1950s and 1960s. In 1960 the Australian Commonwealth Government began looking for ways in which government departments could make use of computers and in 1963 set up the Programmers-in-Training scheme. This was later taken over by the Colleges of Advanced Education and became the template for many future business computing tertiary courses. Computing in schools made a minor start in the early 1970s with a few schools teaching programming in Maths classes using punch cards that were run at a local university. Arrival of the low-priced microcomputer in the late 1970s changed the situation dramatically with many schools quickly making use of them in education. Initially this involved teaching about information technology, but in the later 1980s computers began to be used in other subject areas.

Keywords: Information technology · Education · Curriculum history · Australia

1 Introduction

It is fifty years since IFIP WG3.4 (Professional and Vocational Education) – Professional and Vocational Education in ICT was formed. Fifty years ago in Australia, like many other countries, teaching about and use of computers in education was just at its beginning. Computer Science had appeared in universities, followed by various forms of Business Computing (which relates closely to WG3.4), but very little was happening in schools. The Australian Computer Society (ACS), founded in 1966, was offering some professional education in computing. The first major change was when the Australian government set up its Programmer in Training scheme in 1963.

There are two aspects to information technology in education: teaching about computers and information technology and using computers in other subject areas. This paper deals primarily with teaching about information technology as, in this period, very little else was done with computers as few academics or teachers had much idea of how they could be used, and there were also not enough available computers.

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2 Computer Education Pre-history

CSIRAC[1], Australia's First 'internally Stored-Program Computer', and One of the world's First, Commenced Operations in 1948 [1, 2].

CSIRAC was located at the University of Sydney until 1956 when it moved to the University of Melbourne. CSIRAC continued in use at the University of Melbourne until 1964 when it was offered to the Museum of Melbourne. It is now on display in Melbourne's Scienceworks museum[2] [1].

Fig. 1. CSIRAC on display at the Museum of Melbourne

University computing education in Australia began at the Department of Mathematics in the University of Sydney in 1947, before CSIRAC was operational, with a course on *The Theory of Computation, Computing Practices and the Theory of Programming*. In 1959 the university offered a *Post-graduate Diploma in Numerical Analysis and Automatic Computing*, followed in 1961 by other computing courses at undergraduate, masters, and doctoral levels. In the University of Melbourne, programming courses were given from 1956 as part of a Bachelor of Science degree, and in 1959 a formal subject in *Numerical Methods and Computing* was developed as part of the undergraduate Bachelor of Arts degree in Pure Mathematics [3]. Various computer courses evolved in the 1960s, but in most cases were still based in schools of mathematics or electrical engineering. It was not until the mid-1960s that computing began to be seen as a separate discipline, and university computer science and information science departments started to appear [4].

In 1968 in the US the ACM published "Curriculum 68: Recommendations for the undergraduate program in computer science" [5], and later its 1978 curriculum recommendations [6] which was widely used throughout the world.

3 Research Methodology – Curriculum History

In the broadest sense, this paper could be seen as a study of how the computing curriculum at both tertiary and school levels developed over the last fifty or so years. It was thus appropriate in this study to make use of the lens of Curriculum History. Goodson [7, 8] who worked mainly with secondary school subjects and how they appeared, evolved, and sometimes disappeared, asserts that "*curriculum history is primarily a study in curriculum rather than a study in history*" [9]. Curriculum history is not a new lens with which to view educational change, dating from at least 1909:

[1] CSIRAC – Commonwealth Scientific and Industrial Research Automatic Computer.

[2] It is believed that CSIRAC is the only remaining first generation computing still intact and on display in the world.

> *"If a history of any educational subject encourages and deepens with us the habit of looking with a keener interest for educational provision to the full social, economic, political and religious needs of a community in a past period, from the point of view of the contemporary aims and scope of knowledge of that period, then the study justifies itself."* (10: vii-viii)

The methods applied in Curriculum History involve documents analysis, oral narratives and life-story interviews of those involved. Two important documents here are *A History of Australian Computing*, a book by Trevor Pearcey [1] creator of CSIRAC, and *The Last of the First - CSIRAC: Australia's First Computer* [2], but neither has much to say about education. The main source of data for this study was thus life history interviews with those involved in computers and education at this time, covering the parts they played. They included Gerry Maynard (O&M Inspector with the PMG and PBS Inspector), Geoff Dober (trainee from a Programmer in Training course), Peter Juliff (academic from a College of Advanced Education), Tony Montgomery (University academic), Bill Davey (secondary school teacher) and Tony Salvas (secondary school teacher). The interviews were informal, but opportunity was given for the interviewees to tell of the part they played in this, and how it was important.

4 The Commonwealth Defence and PMG Computing Projects

In 1957, no computers were in use in business in Australia [1]. The only computers outside universities were at the Bureau of Census and Statistics and the Weapons Research Establishment. In 1960, the Australian Commonwealth Government directed the Commonwealth Public Service Board (PSB) to look at ways computers could be used in administration of the Department of Defence and the Postmaster General's Department (PMG). There was, however, a problem with the severe shortage of people having a good knowledge of computing. Added to this was that after fulfilling the needs of these projects, very few knowledgeable people were left to undertake other computing work (11). Clearly more training was needed, but the universities were then unable to deliver business-related training. It was not possible to get these needed people from overseas as many other countries were experiencing the same problem.

In 1960 the PSB began the needed training by running a twelve-week course in '*Analysis and Design of Mechanised Systems*' [12]. Although this was seen as successful in providing a 'crash course' in computing (11), the Commonwealth Public Service Board saw a need for a complete and more detailed course and so, in 1963, set up the twelve-month Programmer in Training Scheme (PIT). Its 1966 PIT Automatic Data Processing (ADP) Course Outline and Syllabus indicated that:

> *The Public Service Board has been conducting courses in A.D.P. Systems Analysis and Design since 1960. These courses have provided essential training not only to a large number of practitioners in the Commonwealth Service but also to personnel engaged in A.D.P activities in Commonwealth Instrumentalities, State Government Departments and in Departments and Authorities of Malaysia and Singapore. Technical Colleges in Victoria and a number of State and overseas organisations have adopted the course as a basis for their A.D.P. training* [13].

4.1 The Programmer in Training Scheme

These twelve-month courses trained staff in establishing and operating commercial and administrative applications, and involved twenty hours per week of formal class time for one year. They were open only to graduates. The curriculum of the Programmer in Training (PIT) courses had four phases [1, 11]:

- Phase 1 (10 weeks): Introduction to the Course and to the Service (1 week), Computer Equipment and Techniques (1 week), Computer Mathematics (1 week), Programming (5 weeks), Systems Analysis and Design (1 week), Examinations (1 week).
- Phase 2 (12 weeks): Departmental training.
- Phase 3 (12 weeks): Computer Equipment and Techniques (1 week), Programming (4 weeks), Systems Analysis and Design (4 weeks), Statistics (2 weeks), Examinations (1 week).
- Phase 4 (12 weeks): Departmental training.

Maynard [11] points out that:

> *The programming part of the early PIT courses started off with a study of machine code then moved to assembly language before finally getting down to Business FORTRAN, which was a very powerful language developed by Control Data. Later, studies of COBOL and PL1 were also introduced* [11].

The Commonwealth Public Service Board continued to run the PIT courses until 1970 when it handed over their operation to four tertiary institutions: Caulfield Institute of Technology, Bendigo Institute of Technology, Canberra College of Advanced Education and New South Wales Institute of Technology [11]. In many ways the PIT courses could be seen as laying the foundations of later business computing diplomas and degrees offered in Colleges of Advanced Education (CAEs) and Institutes of Technology. The importance of the PIT courses on the developments in business computing and information systems degrees was significant [14].

5 Information Technology Hardware in This Period

5.1 Non-computer Information Technology

Information Technology does not just involve computers, and Oxford University Press [15] defines it this way: "*The study or use of computers, telecommunication systems, and other devices for storing, retrieving, and transmitting information*". Several non-computer technologies that were available at this time and had a use in education included Cassette tape (1963), Videotape – VHS (1976) and CD (1982).

5.2 Early Mini and Micro Computer Technology

It was not until development of the minicomputer that educational computing became easily accessible to universities and CAEs. Significant machines were the Digital Equipment Corporation PDP 11/70 (1975) and the DEC VAX which was introduced in

1977. These were readily accessible to tertiary institutions because of their lower cost than mainframes.

At this time also, a number of computer technologies appeared, leading the way towards affordable microcomputers, and perhaps the most significant was the Intel 4004 Microprocessor (1971). Floppy disks became available in the 1970s and 1980s: 8-inch disk (1972), 5.25-inch disk (1976) and 3.5-inch disk (1981).

5.3 Development of the Internet and Email

Beginning with the ARPANET (1969), after several intermediaries the Internet appeared widely in Australian universities and elsewhere in the world in 1989. It wasn't until 1991 that the World Wide Web became available. Although some forms of email had been available since the 1960s, it was not until the 1990s that it came into popular use with Microsoft Mail, Gmail, Hotmail and Yahoo.

6 Tertiary Courses in Computing

As mentioned earlier, university computing began in mathematics and later also in engineering departments. Computer Science did not appear as a separate discipline until the mid-1960s but held an important place from that time on. From then on 'academic' computer science courses were taught in Melbourne and Monash Universities in Victoria, and later in other universities.

At that time tertiary education in Australia was undertaken in two different types of institutions: Universities and Technical Colleges. University courses were mainly in Computer Science. The universities typically made use of mainframe computers to perform their major processing needs, but Mathematics, Engineering and Computer Science departments more often had minicomputers like the PDP-11.

Peter Juliff [16] points out that in the 1960s, 'computing subjects' in the Technical Colleges taught about punch-card machines, accounting machines and computers. The Technical Colleges were later to become Colleges of Advanced Education (CAE) and by the 1970s were all offering some type of computing course, usually based on the use of minicomputers. Although some courses in Computer Science were offered, most courses were Business Computing related, aimed at: "*developing computer professionals for employment in government and industry*" [17: 8] as what was important in business was not so much the computer itself as using one to perform business functions well.

In the 1970s, CAE computing degrees of a Computer Science nature were offered in Applied Science Faculties, and Business Computing degrees in Business Faculties. Business computing courses in the CAEs did not evolve from university Computer Science courses, but instead their foundation can be seen to have come from the PIT courses, which were "*oriented towards training staff for the establishment and running of commercial and administrative applications of computing*" [11]. This was particularly the case after their operation moved to the Caulfield, Bendigo, Canberra, and New South Wales Technical Colleges. By the late 1980s, Business Computing had come to be known as Information Systems.

Montgomery [18] remarked that it was unfortunate that often Department of Computer Science and Department of Business Information Systems at the CAEs did not work together closely. He argued that "*What should be taught to a Business Information Systems person is in many respects what we are teaching to our Computer Science students: information processing techniques. There should be one decent systems analysis course…*" [18]. This made communication between teaching staff and students in these separate areas quite difficult.

7 Computer Education in Australian Schools

Early in the 1970s a few Secondary Schools had managed to acquire access to mini-computers and made use of these in Maths classes. This was the beginning of the use of computers in Australian schools, but in the later 1970s things began to take off.

In the 1970s and 1980s each state set up its own Computer Education Centre, beginning in 1968 with the Angle Park Computing Centre in South Australia [19]. In the mid-1970s Tasmania set up the Elizabeth Computer Centre and a state-wide timesharing network (TASNET).

To assist schools in coming to grips with this technology, in the early 1980s Victoria set up a system of Computer Education Consultants who were seconded teachers who travelled around schools to illustrate this technology and assist teachers with its use. I was a Computer Education Consultant for Northern Region in Melbourne. In Victoria, the State Computer Education Centre (SCEC) commenced operations in 1985 [20]. At SCEC I held the appointment of Educational Computer Systems Analyst.

Following Seymour Papert's use of a turtle in conjunction with Logo programming, in 1979 a Tasmanian company produced the Tasman Turtle, designed for use with Logo and an Apple II computer [21, 22]. This proved popular both in making programming in Logo more concrete and as a demonstration of the power of robotics [23]. Later a connection was established between Lego and Logo [24, 25].

As a result of the rapidly growing number of microcomputers in schools in the late 1970s and early 1980s, in 1983 the Commonwealth Schools Commission set up the National Advisory Committee on Computers in Schools (NACCS) to provide funding and co-ordination of computers in education nationally [26]. The NACCS report: *Teaching, Learning and Computers* pointed out that *"The widespread availability of a variety of hardware has opened up opportunities for school use of computing that have not previously existed"* [27]. These included:

- Computer Awareness (Computer Literacy) courses in upper primary and lower secondary schools,
- Computer Science/Computer Studies/Information Processing,
- Using computers across the curriculum,
- Curriculum Support including preparation of teaching materials and student records,
- Communications with other teachers, students, and remote databases, and

- Administrative applications for database management and financial management [27].

The most popular machine in Secondary Schools in the late 1970s and early 1980s was the Apple II, while some Primary Schools started to venture into computing with the Commodore Pet. In Victoria in the late 1970s the Technical Schools Division recommended that its schools use the Micromation computer – a multi-user CP/M machine. It then tried to convince the Secondary Schools Division to standardise on CP/M, rather than using the Apple II, Commodore or Tandy. This caused some dispute, but the Secondary Schools decided not to adopt CP/M.

7.1 Educational Software

In the 1970s South Australia, Tasmania and Western Australia had support for developing software and set up the TASAWA consortium for its exchange. Three examples of educational software from overseas at the time were 'Oregon Trail' (MECC), 'Lemonade' (Apple //) and 'Suburban Fox' (Acorn BBC computer). Although having much in its favour, this software had a very foreign outlook – lemonade stalls and fox hunting are unknown in Australia. This highlighted the need for locally produced software, and this soon began to appear, the most well-known and popular being the First Fleet Database from the Elizabeth Computing Centre in Tasmania.

8 Educational Computers Specially Built for Schools

The first 'Personal Computers' appeared in the late 1970s and early 1980s with the most significant for education in Australia being Apple II (1977), Radio Shack TRS-80 (1977), Commodore PET (1977) and Atari (1979). Many others appeared later into the 1980s including Commodore VIC-20 (1980), Acorn BBC (1981), IBM PC (1981), Microbee (1982), Apple Macintosh (1984) and IBM JX (1984). These were, however, incompatible with each other, and in the early to mid-1980s, before the PC and Macintosh became dominant, many countries around the world worked to develop their own educational computers. These included: Poly Computer (New Zealand, 1980), Acorn BBC Computer (UK, 1981), Compis (Sweden, 1981), ICON Computer (Canada, 1983) known locally as the 'Bionic Beaver', Piccoline (Denmark, 1984) and Tiki (Norway, 1984).

In 1985, the Australian Government decided that, like these other countries, Australia should develop its own educational computer, mainly to provide an opportunity for the Australian computer industry to manufacture it and provide software for this new machine. Another reason was that, as mentioned earlier, much of the available software at the time had a very foreign outlook – American or British, and little things like the Apple Macintosh's 'Trash Can' were annoying as in Australia we use a 'Rubbish Bin' (Fig. 2).

Fig. 2. Bunyip stamp

The Government set up Educational User Requirement and Educational Technical Requirement working groups to develop the computer [28]. These groups met and worked in Canberra and came up with a design for the Australian Educational Computer. When all the design work was done, however, the Australian Government decided not to proceed, and the computer was never built. Like Frankenstein's monster [29], the Australian Educational Computer was never sufficiently 'real' [30] to be given a name of its own, but I will call it the Bunyip[3]. Those of us involved in this project had assumed that the computer would be manufactured by an Australian company such as Microbee, but in retrospect, after the PC and Apple Macintosh came to dominate the market in the late 1980s, the decision not to proceed was probably correct [31].

9 Computers in Secondary Schools

Early in the 1970s a small number of Victorian Secondary Schools began to make some use of minicomputers purchased through innovation grants from the Commonwealth Government. Burwood High School obtained a PDP-8 (initially loaned from DEC), McKinnon High School purchased a Wang computer, but because of the high maintenance cost shared it with Box Hill High School, and Maribyrnong High School also used a Wang computer. These computers were expensive, not very powerful, and quite difficult to use. They were typically based in Maths departments to teach programming. In most cases this was the result of their teachers' own experiences in Computer Science at university [32].

In 1974, Monash University introduced MONECS (Monash Educational Computer System) that made use of mark-sense cards to teach programming in FORTRAN or BASIC to school students [33]. This provided a big computer education impact on schools at this time, as before the advent of the microcomputer it was impossible for an average school to offer students hands-on access to a computer [33]. With MONECS, students would mark the cards in class and their teachers would take a batch of cards to a local university to run on its PDP-8 computer. This allowed a class of 30 students to each get two program runs in a one-hour period [34]. Unfortunately, in most cases the initially results were disappointing for the students as they involved finding many syntax errors. At this stage, like the universities, schools saw computing as a branch of mathematics concerned with algorithm design, and most teachers involved came from a Maths/science background.

In 1978, the Victorian Education Department's Secondary Mathematics Committee, recognising the potential of computers in mathematics education, set up a Computer Education Subcommittee. They then formed the 'Computer Travelling Road Show' which visited schools around the state and performed demonstrations to teachers of computer applications in mathematics, commerce, word processing and graphics. They normally showed these on an Apple II computer [35].

9.1 Computer Awareness Courses

By the end of the 1970s, microcomputer like the Apple II, Tandy TRS-80 and Commodore PET, being much cheaper than minicomputers and less difficult to use than arranging for the use of mark sense cards on a university minicomputer, changed things considerably in schools. Costing about A$2,000 a 16 KB Apple II[3] was affordable by most schools, but expensive enough that most schools could only afford one or two machines. This placed restrictions on how they could be used. But the question was, apart from teaching programming, what could you do with a computer?

In Australia, like most countries in the late 1970s and early 1980s, few teachers had any knowledge or experience in using computers. A report by Anne McDougall, commissioned by the Victorian education department, noted that:

> *Computers have been called electronic 'brains' and there is no doubt that in the popular view, they are surrounded by an aura of mystery and are credited with powers they do not possess. The result is that most people outside the computing profession have attitudes of awe and fear towards computers and feel helpless and powerless in a highly computerised society* [36].

It was thus seen that students needed to be made *aware* of computers and what they could and could not do, and so *Computer Awareness* courses[4] began to be offered in Secondary Schools when the situation was quite different to what it is today. A typical Computer Awareness might have the following three components:

1. What a computer is and how it works, computer programming (probably in BASIC), history of computer technologies.
2. Uses of information technology in science, engineering, and business.
3. The implications on society of increased use of computers [33].

9.2 Secondary School Computer Science Courses

In 1981, Computer Science was first offered as a Higher School Certificate (Year 12) subject in Victoria. Year 12 subjects are important for university entrance and so it was disappointing when both Melbourne University and Monash University did not allow it for admission for their courses. They said that they did not see the 35% external examination as sufficient. The subject assessment also comprised option work with 35% school-based consensus moderation and 30% practical work. The universities consider the subject to have insufficient serious academic worth, and not appropriate at a secondary school level. The other Victorian universities and the CAEs however did accept Year 12 Computer Science as a valid subject [37].

9.3 Use of Computers in Other Subject Areas

Probably the first use of computers in different subject areas began in 1982 with the release of the First Fleet Database software by the Elizabeth Computing Centre in Tasmania. This attracted immediate interest as students were keen to see if they had a convict relative who arrived from England in 1778. The software was available for Apple II computers and required no background knowledge of computers to use [38].

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[3] The Apple II used a cassette tape recorder as storage and a television set as a monitor.

[4] In some countries these courses were called Computer Literacy.

Use of computers in accounting, science and other subject areas followed, but discussion of this is beyond the scope of this paper.

10 Conclusion

Fifty years ago in Australia, Computer Science was underway in universities, and the government and business were just starting to make use of computers. The Programmer in Training scheme had run successfully and was just transferring to the CAEs. Courses in Business Computing were beginning. Only a few schools were then using computers, and these for programming in Maths classes. It is difficult now to look back at this period in education as it is so different to today when almost every student has an iPad, and computers are used for many functions in schools. But why is it worthwhile to look at computer education in the 1970s and 1980s? Will this help us to understand things today or to plan how to deal with future educational technologies? As George Santayana [39] once said: "*Those who cannot remember the past are condemned to repeat it*."

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Computational Thinking – Forces Shaping Curriculum and Policy in Finland, Sweden and the Baltic Countries

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Abstract. Through an increased focus on computing and computational concepts in the school curriculum the Nordic and Baltic countries are preparing to equip themselves to explore the opportunities that Industry 4.0 and beyond can offer. Realising this vision has inevitable consequences for the curriculum in compulsory schooling (preschool to year 9) as new scaffolding for the development of new competencies is needed, and adapting to technological change involves also integrating Computational Thinking topics and skills, as well as elements of programming and digital literacy into existing curricula. The Nordic countries (Finland and Sweden) have chosen not to create a new school subject, advocating the integration of these skills and competencies into existing subjects such as Arts and Crafts, Language, Mathematics and Technology. In contrast, the Baltic countries emphasise introduction of a subject called Informatics in which programming and Computational Thinking skills and competencies are intended to be developed. This paper provides an analysis of approaches taken to scaffolding access to Computational Thinking in the Nordic and Baltic countries.

Keywords: Computational thinking · Digital skills · Technological fluency

1 Introduction

Programming and Computational Thinking (CT) have emerged as a hot topic in the redesign of national school curricula over the last decade. Driving this debate is a belief that the increasing presence of digital computing systems in all sectors places demands on compulsory education to respond by adjusting curricula to equip citizens to both understand and contribute to this new world.

The Nordic and Baltic countries responded rapidly in terms of the integration of computing in their school curriculum, however, they have adopted rather different

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approaches. This paper contributes to the debate by exploring the power factors and positioning of CT in the national educational political debate in Estonia, Finland, Lithuania and Sweden.

In the European context, the Nordic and Baltic countries have spearheaded the integration of computing in their school curriculum. The vision has been to realise competitive benefit from small size, unified culture, advanced infrastructure, digitalisation, and well-established, centralised national curricula. These benefits result in three driving forces acting to produce nation-wide changes to the curriculum, and in consequence the development of computing and digital literature addressing the sector. The refinement of the computing syllabus is necessary to ensure a consistent learning trajectory, as well as the establishment of this new subject among other subjects with a longer history. Similarly to mathematics, computing would fit as an entry criteria for Computer Science (CS) studies, and to a lesser extent also for natural sciences. This adds to the relevance of the subject, and makes it a reasoned choice for intentional students orienting toward these domains.

The main contribution of the current paper is to chart and analyse curricular developments in the Nordic and Baltic region with a focus on how curricular pressure can be understood and traced over time. This study benchmarks the current situation of CT in curricula of Nordic and Baltic countries, and targets the following questions:

- RQ1: What is the current status of Computational Thinking in K-9 education in Nordic and Baltic countries?
- RQ2: What factors influence national priorities in digital skills curricula for all citizens?

2 Computational Thinking in Compulsory Education

Curricula are one of the central instruments through which policy makers set strategic direction and establish common goals at the national level in the context of compulsory schooling. By “compulsory schooling” we mean education provided by the state to all citizens in the school years from preschool to year 9, thus comprising the first 10 years of a citizen’s engagement with formal education.

The concept of compulsory schooling as a means to equip people for a productive life in human society can be traced back to educational policy makers in the early 19th century [1]. By examining existing and past curricula, it is possible to deduce the values, ideals, and how these are shaped by the societal and political agenda. We argue that the evolution of technology places civilisation on the cusp, and that radical change in education, especially in regard to reforming the curriculum is underway.

An example of a similar situation can be found in the Soviet technological accomplishments resulting in Sputnik I and II in 1957, which prompted much of the Western world to examine their technological capabilities, research programmes and education systems [2]. In a similar vein international comparisons, such as PISA and TIMMS, have provoked both reflection and redesign of curricula in multiple countries [3]. A common theme is the desire to ensure technological competitiveness, which is also one of the aspects behind the move to address computing topics in national curricula [4]. Other aspects of the debate include promoting democracy and gender equality, using the argument that every child has a right and opportunity to learn digital skills, and that these are comparable to the more established civic skills to which we have become used. In Nordic and Baltic countries, curricula are state-run and centralised to ensure the equality of students and schools regardless of their resources or location, whether in rural or urban environments.

The first traces of discourse of CT date back to the late 60's - early 70's. Seymour Papert was a significant influence in the international discourse. His Logo programming language made its debut in 1967 with an apt pedagogical rationale derived from the theory of constructivism [5]. The CT idea was popularised by Jeannette Wing in her 2006 paper [6] and the definition of the concept and what is included has been hotly debated over the last decade [7–9]. During the ensuing decades, digitalisation has accelerated and brought digital devices within the reach of nearly every citizen, and transformed a significant segment of the workplace, further strengthening the ideas behind the goal to equip all citizens for future agency in society through the teaching of digital skills. In 2014, Mannila [10] summarised the situation of CT in education of multiple European countries and USA Mannila's study pinpoints the lack of qualified teachers as a crucial bottleneck, the impact of which cannot be underestimated in terms of the importance of the teaching of computing to a broader segment of the population.

However, it is clear that at primary school, teaching the basics of CT via unplugged activities is not particularly demanding on either teacher or pupil, thus, achieving low level goals in relation to CT should be achievable without an extensive CS education. In terms of enhancing teachers' knowledge to achieve higher levels of computing education, we observe that universities and teacher associations provide courses, material and even certificates to support this process in the Nordic and Baltic regions, however more needs to be done [11]. In-service teacher training is provided by a range of organisations. In Finland the Association of mathematics teachers - MAOL, offers a variety of courses, and in Sweden similar courses are offered by universities through the government agency Skolverket [12]. In Lithuania, a variety of courses is offered by Vilnius University [13], while in Estonia similar initiatives are provided through the Lifelong Learning Strategy (2014–2020) that also targets the provision of open material for school use [14]. In addition, there are a number of European funded projects, for instance, the TeaEdu4CT ERASMUS+initiative[1] that provide extensive teaching resources for teacher education programmes, and practising teachers.

At secondary school, CS/CT is provided either as a separate subject, or integrated within other subjects, mainly mathematics. For instance, Baltic countries have been swinging between separation and integration since late 60's, see Fig. 2. In PISA, mathematics is the closest counterpart to CS/CT if not the very subject where the CT has been integrated.

[1] https://www.fsf.vu.lt/mokslas/projektai/tarptautiniai-projektai/erasmus?layout=edit&id=2720=future-teachers-education-computational-thinking-and-steam.

2.1 Nordic Countries

Computational Thinking education in the Finnish and Swedish systems have a common ground based on the idea that CT should be integrated into subjects such as Language, Mathematics, Arts and Crafts, and Technology, rather than introduced as a separate subject. This approach differs from that adopted in the UK, USA, Germany, New Zealand and Australia, where computing and informatics were introduced into the curriculum as a new subject to address these educational challenges. The Nordic approach has assumed that courses in languages will be able to handle the relevant aspects of digital literacy, in particular those that aim to develop critical thinking and reflective learning capabilities. This content is increasingly emphasised in the national curricula for Swedish language and literature over the past couple of decades, culminating in the current version [15]. The language curriculum emphasises the influence of digitalisation on the curation of information, including internet media, and a focus on large scale systems operating on big data to derive modern data-driven platforms, primarily Google and Facebook, which have significant impact on information provision.

The political discourse underlying this strategy is that it will be necessary to enhance awareness of the data these systems collect about users, and the impact of algorithms and machine learning on social media experience. Examples include social bubbles of like-minded people, emotion engineering [16], targeted advertising based on our preferences, and even manipulating users' political views, which has been reported in the much debated Brexit process [17] and the 2016 USA presidential election [18].

Computational Thinking in Finland through Language, Craft and Mathematics. After introducing programming as an elective course in 1984, the 2014 Finnish National Curriculum (FNC-2014) established general goals for teaching programming in compulsory education [19]. FNC-2014 introduces hands-on experimentation (e.g., programmable robots) as a precursor to CT, emphasising using robots, and following stepwise commands. At the secondary level, CT is integrated into mathematics, the motivation for this approach is that aspects of mathematical thinking applied in problem solving are analogous with CT. There are also expected benefits for mathematics education, in particular in the area of algebra where CT is expected to improve outcomes due to transfer effect [20].

However, the FNC-2014 programming content is painted with a broad brush: logical and algorithmic thinking are mentioned, as well as problem-solving through decomposition. These goals are the integral parts of "computational thinking" yet the CT term does not appear in the FNC-2014 text. Concrete guidance for teachers is largely lacking, and the targeted computer science concepts and skills are left undefined. Indeed, the clarification of the learning goals for CT has largely been delegated to book publishers in Finland. The biggest publishers (SanomaPro, Otava and Edita) seem to have reached consensus to publish texts promoting Scratch at primary and Python at secondary level [21].

Finnish PISA results have been falling since 2006, especially in mathematics. Male students and minorities are over-represented at the lower end of the results [22, 23] see Fig. 1, and the gap between native and immigrant students is the largest [24]. Too open and unstructured learning environments provide no support. Instead of the anticipated empowerment, students may be left overwhelmed and clueless about how to study. [25] also points to a correlation between increased online and digital learning and deteriorating learning outcomes, e.g., in PISA-2015 [26]. To counter this trend the Ministry of Education provides new support through the "Right to Learn" initiative [27], in particular the New Literacies [28] sub-programme. New Literacies highlights source criticism, critical thinking and a thread of programming and CT as an integral part of new literacies. During the next few years, New Literacy pilots are scheduled in 100 schools to gather evidence, and create CC-licensed material for other schools, including material for CT.

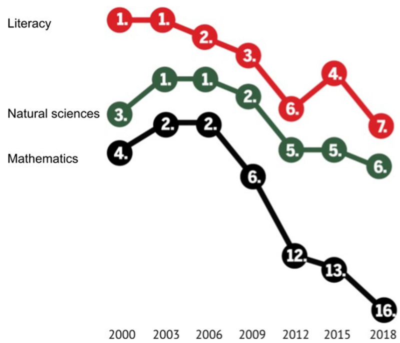

Fig. 1. The drop of PISA results in Finland, retrieved from the Ministry of Education

Computational Thinking in Sweden, Integration with Mathematics and Technology. Despite early forays into computing in schools in the 1980's[2], the subsequent Swedish education policy has emerged as more conservative than the Finnish model. Programming was ensconced in the national curriculum for the second time in 2016. However, the educational act for compulsory education (SWEA) [29] did not include computing or programming prior to 2017 [30]. The subject of Technology and the corresponding upper secondary school programme, an elective programme, (teknik programmet) provided access to similar content, also including courses covering various aspects of computing.

In 2012, the Swedish government established a committee with the task of giving recommendations and guidelines for how Sweden can, and should, benefit from digitalisation. In a report published in March 2014 [31], the committee emphasises the need for an additional focus on digital competences in national curricula. One concrete recommendation is for programming to be introduced as a cross-curricular element in already existing subjects. This ultimately resulted in programming being included into the compulsory school subjects Mathematics and Technology. The associated political discourse also emphasised the need to enhance technological fluency. The assumption

[2] https://undervisningshistoria.se/programmering-i-skolan.

is that technology is a transverse skill, can be applied to all subjects, and that the necessary computing skill set can be partially addressed in the digital literature curriculum.

In 2015, the government commissioned the Swedish National Agency for Education to propose content in the national strategy for digitalisation. As a result, the curriculum for compulsory school was revised and digital competence was added. The revised curriculum has been in operation since 2018 and describes digital competence as follows: a) to understand the impact of digitalisation on human society; b) to be able to use and comprehend digital tools and media; c) to adopt a critical and responsible attitude to change; d) to be able to solve problems/challenges and implement theoretical solutions in practice. After considerable consultation with the academic and industry sectors the revised compulsory curriculum was released in 2017, and became mandatory from August 2018 for all schools in Sweden.

The revised 2018 curriculum stipulates the following four main goals for students' digital competence:

- to learn to put one's own creative ideas into action and learn how to solve problems,
- to be able to use digital tools and media,
- to understand the digital transformation of society and how it affects us,
- to be critical and develop a responsible approach to digital technology.

The Swedish interpretation of digital competence includes aspects of digital literacy, such as the importance of critical thinking, source criticism, fact checking, and safe use of the internet by being aware of security threats, as well as attempts at information manipulation. The key areas are considered as critical components of the strategy to establish Sweden as a strong democracy in alignment with Swedish policy in the 21st century.

2.2 The Baltic Countries

The Baltic countries started to reform informatics education, and ever since it was introduced, it has been swinging between integrated and separated subjects, as illustrated in the Fig. 2. The swing started from an independent optional subject and currently, in 2021, has almost returned to the starting point.

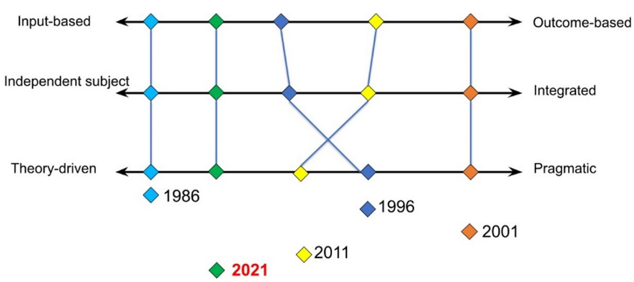

Fig. 2. The swing of informatics curriculum between integration and separation.

Computational Thinking in Lithuania Focuses on Informatics. Lithuania has taught informatics at schools for almost 40 years [32]. In 1986, informatics was first introduced as a school subject, and it focused on logical principles of computers, information transmission, storage and processing, and algorithms, particularly data types and basic control structures of programming (based on Logo and Pascal). Before that, Lithuania had already established the Young Programmers' School, a Correspondence school, and one of the first programming schools for pupils in the world. The School triggered a number of research articles, books, contests and competitions [33]. In 1981–83, lessons in programming for beginners were even published in one of the biggest daily newspapers in Lithuania.

The most significant influence on the status of informatics education was the introduction of the informatics maturity exam in 1995. Those who pass the informatics exam have enhanced opportunities to enter CS-related studies in higher education. The test also provides a reliable indication as to whether a student has the aptitude to study informatics. The informatics exam consists of two parts: one part (over 50% of the full exam) is allocated to programming, while the rest concerns computer literacy and applications.

A revision of the informatics core curriculum was initiated in 2005, expanding the scope from two to four years' teaching time (in total 136 h) with more focus on developing algorithmic thinking and applications. The teachers were formally qualified, usually with a bachelor's or master's degree in informatics, combined with mathematics. 5th and 6th grade pupils are introduced to the basics of informatics based on Logo or Scratch. In grades 9 to 10, more advanced students are recommended to enrol in the optional module of algorithm design and coding.

In 2019, the Lithuanian Ministry of Education, Science and Sport developed new guidelines for pre-school, primary, basic and secondary education[3]. The general curriculum framework is a document governing the content of national level education, which helps teachers to scaffold performance in relation to learning goals, and the levels required to attain them.

The Ministry and the National Agency of Education manage all update efforts within the framework, documents under consideration and planned events are published online (www.mokykla2030.lt). In 2020, one hundred primary schools started to pilot the proposed informatics curriculum. The pilot targets the development of learning resources and textbooks, as well as teacher training. The full-scale implementation commences in 2022.

The revised curriculum includes fundamental CS topics such as programming, problem solving and algorithms, data mining, data representation and information, networks and communication, digital technology and human computer interaction, security, and privacy and ethical considerations. Attention is given to the key concepts in the field, and the constructive aspect of the discipline. Figure 3 illustrates six areas of informatics education with main focus on four core areas: 1) Data mining and information, 2) Algorithms and programming, 3) Technological problem solving, and 4) Digital content creation.

[3] https://www.e-tar.lt/portal/lt/legalAct/e3e9269009e511ea9d279ea27696ab7b.

The most pressing current challenge is to redesign an existing informatics course in upper secondary school (grades 11–12) so that it would also introduce some new technologies such as artificial intelligence, machine learning, and big data. The renewed informatics curriculum at upper secondary school is expected to be ready for incorporation into the new national curriculum in 2023.

Fig. 3. The areas of informatics curriculum

Computational Thinking and Estonia's Commitment to Digitalisation. The national curriculum for a newly independent Estonia was introduced in 1996. In this process, a new elective school subject called informatics was introduced that comprised four 35-h modules for grades 10–12. The new informatics curriculum contained no coding, algorithms or other abstract elements of CT, as opposed to the theoretical CS course that was forcibly introduced into the curricula of all Soviet Union's republics in 1986. Instead, the focus was on everyday use of computers: word processing, spreadsheets, computer graphics, and internet. The next version, National Curriculum 2001, dismissed informatics completely, which resulted in a sharp decline in teaching popularity. While removing informatics, the 2001 curriculum introduced instead a set of compulsory ICT skills that were assessed by the National Exam Centre at the end of basic school, in the ninth grade.

The current renewed national curriculum came into force in 2011. One of the four prioritised elective subjects is informatics, and it is recommended by the policy makers. This informatics curriculum outlines syllabi for two 35-h courses in basic school:

- Y5/6 working with computer: word processing, file management, digital presentations, spreadsheets, internet search, citations, plagiarism, evaluation of online information, cyber-threats, digital identity;
- Y8/9 information society technologies: online communities, blog and wiki usage for digital content creation, metadata and annotations (tags, bookmarks), online content aggregation (e.g., RSS), collaborative digital project, digital safety.

The high school curriculum (grades 10–12) does not mention informatics as a subject, but describes a set of new technological elective courses under Natural Sciences domain, each accompanied by a textbook, e-course in Moodle, tests and educational videos. Elective courses are: 1) inquiry-based learning (data collection, data analysis and visualisation in Excel, presenting the research results); 2) introduction to programming and software development; 3) robotics and mechatronics; 4) 3D-modelling; 5) Geoinformatics.

As in the Nordic system, there is a tension in the Estonian national curriculum and educational practice between the content of informatics and generic digital competence. Are these the same subject, partly overlapping, or completely different things? In 2014, a minor update to the national curriculum introduced digital competence as one of the eight compulsory key competences (e.g. the DigComp model). An online test of digital competence has been conducted in grades 9 and 12 since 2017 by HARNO, an agency responsible for exams. In some schools, teaching digital competence is the responsibility of the informatics teacher, whereas schools without informatics teachers have integrated the teaching of digital competence into other subjects. The third group of schools tries to offer both: informatics as a separate subject focusing on development of CT and digital competence nurtured by other subject teachers.

The development of a radically changed informatics curriculum for primary and upper secondary schools was led by the HITSA agency 2016–2019. This curriculum is still classified as an "unofficial document", but the majority of primary schools already apply it to some extent in grades 1–6, thanks to the corresponding online textbook for informatics (digiopik.it.ee). The new informatics curriculum for high schools was introduced in 2019, but its uptake is significantly poorer compared to primary school, with less than 10% of high schools offering it. The Fig. 4 illustrates the new elective courses for grades 1–6 and 10–12. The most complicated stage is grades 7–9, due to no "free space" in the national curriculum.

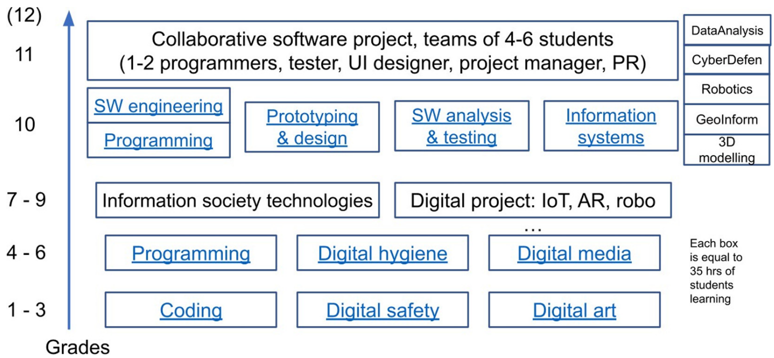

Fig. 4. The proposed K-12 informatics curriculum

The new task force group has been formed to design a solution for this grade level by 2022. The key idea is to redesign an existing informatics course "Information Society Technologies" to introduce new technologies such as artificial intelligence, augmented reality and big data analytics in grade 7. The school renewal has been successful, which manifests in international comparisons, such as PISA, see Table 1. The new additions to informatics curricula, such as artificial intelligence and machine learning, are intended to be incorporated into the new national curriculum in 2024.

3 Discussion

As Fig. 2 illustrates, the Baltic countries have acted in a more synchronised manner. Estonia has taken the lead, for instance in open e-textbooks that are prepared together with academia, and its advancements are well disseminated within other Baltic countries. Adoption among policy makers is promoted by the results reached in Estonia, such as a constant improvement in national PISA results of mathematics (Table 1) [34].

Table 1. Math PISA results of 2006–2018

	2006	2009	2012	2015	2018
Finland	548 (1)	541 (2)	519 (12)	511 (13)	507 (16)
Sweden	502	494	478	494	502
Lithuania	486	477	479	478	481
Estonia	-	512 (11)	521 (11)	520 (10)	523 (8)

Finland and Sweden have adopted integrative approaches to the introduction of CT to an already full curriculum, through the subjects mathematics, craft and (in Sweden) technology. Efforts in the Nordic countries are not as coordinated as the Baltic approach, but they have considerable similarities, and face common challenges. Educators and policy makers are faced with the necessity to establish priorities between existing subjects and the new demands of the digital transformation of society.

The problem with integrating CT is, however, that teachers of the target disciplines (languages, craft, technology and mathematics) should be knowledgeable enough to teach programming basics. In addition, the learning goals should be defined in detail and adhered to. The current situation of vaguely specified, broad brush descriptions of the CT goals and content to be included in the curriculum; such as “digital fluency” or “computational thinking” tends to frustrate teachers. Leaving aside the issue of poor definitions of CT, acquiring the required knowledge to teach CT has also been largely left to the teachers alone.

The selection of the programming paradigm has also been largely left to teachers and book publishers. However, the prevailing CT definitions provide a strong impetus towards the imperative programming paradigm represented by languages such as Python and Scratch. While some arguments have been advanced for adopting a functional approach, this is a marginalised area [35, 36]. The rationale for adopting a functional paradigm is the close conceptual correspondence with mathematics, and the absence of contradicting concepts, such as mutable data. However, this argument has gained little traction among policy makers. To establish its position, CT/CS should consider following the lead of mathematics. A more concise definition for CT should be developed, and that definition should be linked to a consistent learning trajectory. Ideally elements of the CT learning outcomes would be added to the matriculation exam.

4 Conclusions

This paper summarises the state of play in the introduction of CT concepts and competencies into compulsory education in two Nordic and two Baltic countries. We conclude that while much progress has been made into incorporating CT into the Nordic and Baltic school curricula, there is still a considerable way to go. The major dilemma facing policy makers and curriculum designers is whether computational thinking and digital skills should be integrated into other subjects, or provided as a separate subject. Since then, various CT teaching experiments have ranged from optional to compulsory, and from a separate subject to wholly integrated into one or more existing subjects.

The trend we see from our analysis is that this integration has focused most often on mathematics or handicrafts in Finland, with Sweden also making efforts to include some content in language and technology subjects. Our observation is that integrating CT into other subjects makes the coordination of content and learning outcomes considerably more complex, while offering the advantage of enhancing the relevance of CT in familiar contexts.

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Changing Computer Curricula in Australia

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Abstract. This paper was developed from a symposium entitled 'Moving on with informatics/computer science curricula – challenges and opportunities.' It provides an Australian perspective for that debate. From 1901, the eight Australian States and Territories accepted constitutional authority for school education. Hence, a nationally developed curriculum only arose in 2014, for optional adoption. Computers were initially included as a general capability to enhance learning in all subjects. This focused on Office-suite applications. In 2016, the new Digital Technologies subject was added to the curriculum. This paper looks at the adoption of the new subject and changes proposed in the 2021 public consultation draft Review. We reveal the answers to the following questions about the proposed update for Digital Technologies: 1. Will Australia abandon the general ICT capability (as in the UK) to provide greater focus on Digital Technologies? 2. Will Australia put a greater emphasis on coding/programming than the current meagre mention? 3. What does a tutor of pre-service teachers think about the proposed changes?

Keywords: Digital technologies curriculum · Coding proportion · Pre-service teachers

1 Introduction and Context

1.1 A Nationally Developed Curriculum

Curriculum responsibility in schools was vested with the states of Australia by the constitution of 1901. A nationally developed curriculum for school subjects was only made available from 2014 and was incrementally adopted or appropriated by the states, in various ways.

At that time, computers were written into the nationally developed curriculum as a general capability to enhance learning in all subjects. This was designated as the Information and Communication Technologies (ICT) general capability. The core ICT capability was conceived as comprising Investigation, Communication and Creation. These elements are underpinned by 'managing and operating ICT' and 'applying social and ethical protocols and practices.'

Because different learning areas of the curriculum were developed along a staggered timeline, the Technologies learning area curriculum did not become available

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until 2016. This contains the Digital Technologies subject. At its core is the concept of creating digital solutions, approached by processes and production skills. Underpinning these are Digital Systems and Representation of data.

Therefore, the Digital Technologies subject is quite separate from the ICT general capability. Very few teachers had computer education in their own schooling, or have encountered it in their pre-service training. While ‘creating digital solutions’ is core to the subject, coding or programming are mentioned very sparsely in the document. The design-time for this subject is 30 min per week in Years Foundation-2, 40 min for Years 3–4, an hour per week in Years 5–6, and 80 min per week in Years 7–8.

In 2020, the Australian Government agency responsible for the nationally developed curriculum announced the commencement of a Review. This review produced a public consultation draft of a new version of the curriculum in late April 2021.

The Review had the key task of simplifying the curriculum. Partly due to the staggered implementation, teachers initially focused on core subjects, and had felt overloaded as additional subjects such as Digital Technologies were released.

Recent indications are that principals and teachers confound the current ICT capability and the Digital Technologies subject. 30% of tools and websites used in Digital Technologies were seen to be content management systems, office suites and other generic tools rather than subject content specific software applications.

There are some key issues to be examined. First of all, there is tension between the two ways in which computers are used in Australian classrooms (general ICT capability and discrete Digital Technologies subject). It remains to be seen how these tensions will be addressed by the curriculum revision. Second, programming or coding is a key component in computing curricula in other countries – we will examine this aspect in the proposed revision of the Digital Technologies curriculum. Finally, it is useful to understand how teachers respond to the proposed revision. One of the authors had worked as a Digital Technologies Education tutor, and informally discussed the topic with some pre-service teachers. This article is now framed in such a way to find the answers to these three questions: 1. Will Australia abandon the general ICT capability (as per the UK) to provide greater focus on Digital Technologies? 2. Will Australia put a greater emphasis on coding/programming than before? 3. What does a tutor of pre-service teachers think about the proposed Digital Technologies curriculum changes?

After consideration of these research questions, we show how they illuminate the four focus points of the symposium on “Moving on with informatics/computer science curricula – challenges and opportunities”. These were:

1. What is driving the emphasis of specifications for informatics/computer science curricula in different countries?
2. What do we know about how students learn some of the core concepts and processes of informatics/computer science that will enable us to design structure and progressions in curricula?
3. How should we incorporate new challenges associated with rapid developments in artificial intelligence and machine learning into informatics/computer science curricula?
4. What is the relationship between an informatics/computer science curriculum and other academic disciplines?

The responses to the three questions will shed light on the focus points of the symposium, as shown below.

1.2 The Proposals of the Review

The Public Consultation draft release in late April 2021 contained two main changes in the curriculum concerning student computer use:

1. The ICT general capability will be renamed as the 'Digital Literacy' learning continuum.
2. The Digital Technologies subject will grow from 43 to 71 Content Descriptors.

The Digital Literacy learning continuum [1] differs from its predecessor (ICT) in several ways. Digital safety and wellbeing replace social and ethical practices. Thus, there is a greater emphasis on cyber-safety and management of personal digital authentication tokens. Recognition of intellectual property, referencing and copyright is now balanced with exploration of creative commons, collaboration and information exchange. Figure 1 shows the proposed new structure and the new nomenclature.

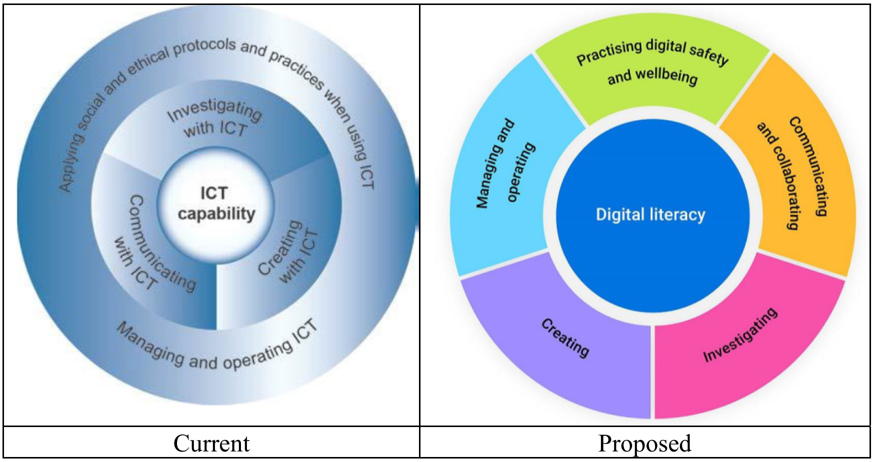

Fig. 1. The organising elements for the ICT general capability and the proposed Digital Literacy replacement (ACARA, 2016, 2021)

The Digital Technologies curriculum is due for a massive shakeup if the review proposal proceeds [2]. The current and proposed structures for this subject are shown in Fig. 2, with minor rearrangements of the elements.

The biggest change is a massive increase in Content Descriptors from 43 to 71. This appears designed to make them more understandable to teachers. More complex ideas have been broken into smaller components. For example, in Years 5–6 (student ages 10–12 years): "*Examine how whole numbers are used to represent all data in digital systems*" has been replaced by: "*Explain how digital systems represent all data*

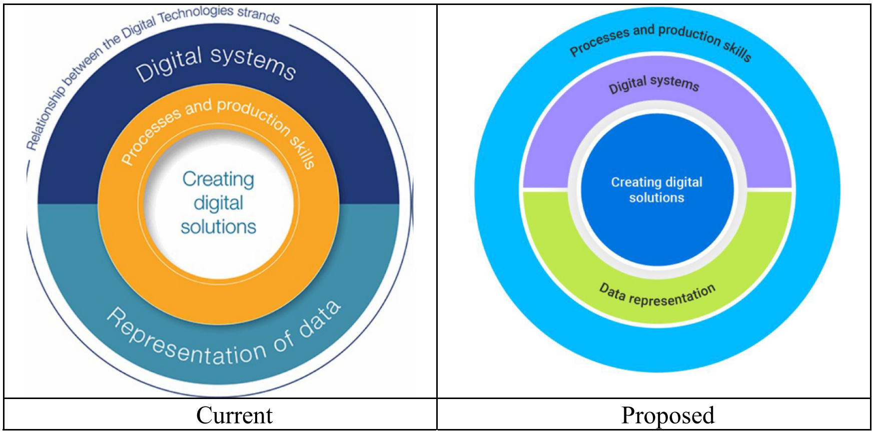

Fig. 2. The organising elements for the Digital Technologies subject (ACARA, 2017, 2021)

using numbers" and "*Explore how data can be represented by off and on states (zeros and ones in binary)"*.

This kind of simplification can help teachers by using simpler language while introducing otherwise hidden concepts (such as binary). The increase in more explicit language throughout the new proposal is likely to be well accepted by teachers.

Another noticeable change is the recognition that early childhood students (referred to as Foundation students, aged 5–6 years) have quite distinct learning needs from Years 1 & 2 (6–8 years old). These Foundation students are asked to engage with fewer concepts and use play-based learning. One content descriptor requires them to be taught to *identify some data that are personal and owned by them*. This is quite complex, but indicates a perception that cyber-safety awareness begins at a very young age.

2 The Issue of Coding

Having described the current status of computers in the Australian curriculum, and the impending changes, we now look at the issue of coding and compare this with the situation in other countries.

2.1 The Current Place of Coding

One of the consequences of the proposed increase in content descriptors for Digital Technologies is a proportionate reduction in coding-relevant teaching activities. The key concept in the subject is 'creating digital solutions'. The language used in the original curriculum does not ask students to code or program, but instead asks for them to *implement simple digital solutions* (Years 3–4).

In the overall Technologies learning area, computational thinking is fundamental to the subject. Computational thinking is defined as a "process of recognising aspects of computation in the world and being able to think logically, algorithmically, recursively and abstractly" [3]. The way digital solutions are to be created in the subject is through "using combinations of readily available hardware and software applications, and/or specific instructions provided through programming". It is quite clear from this language that coding or programming is just one of the methods students can employ.

To put programming/coding into context in the Australian Curriculum, it is useful to establish the format used. For each age range there is a description, a list of content descriptors (with elaborations), and the assessable achievement standards. Table 1 shows the current proportion of content descriptors in each age range where programming or coding is mentioned.

Table 1. Proportion of coding in the current Australian Digital Technologies subject

Student years	Total content descriptors	Content descriptors including programming or coding	% of coding in the subject
F - Year 2	6	0	0%
Years 3–4	7	1	14%
Years 5–6	9	2	22%
Years 7–8	10	1.5	15%
Years 9–10 (optional)	11	1.5	14%

Programming/coding is first mentioned with respect to visual programming in a content descriptor ("implement simple algorithms as visual programs involving control structures, variables and user input"), in the elaborations for Years 3 and 4 and in the achievement standards. Visual programming is a way of coding using coloured shapes on the screen. This recurs in Years 5 and 6.

In the current Australian curriculum, by Years 7 and 8, general-purpose programming/coding languages are mentioned in the description, and this occurs for the first time in content descriptors ("implement algorithms and modify and debug programs involving control structures and functions in a general-purpose programming language") at this level. "Use of a programming language" is also mentioned in the current Achievement Standards, so students are to be assessed on their programming skills for the first time once they reach this age (high school). In Years 9 and 10 (where Digital Technologies becomes an optional subject), we now see object-oriented programming/coding in the description, in two content descriptors ("implement, modify and debug modular programs, applying selected algorithms and data structures, including in an object-oriented programming language"), and in the achievement standards.

Overall, the current curriculum design has students progressing through the core F-8 Digital Technologies subject with visual coding in Years 3–6 and only undertaking general purpose programming/coding in Years 7 and 8.

2.2 Coding in Other Countries

In other countries, we see a different perspective on computer education in schools. In Singapore, for example, coding classes for primary school students were mandatory from the start of 2020 [4]. The initiative aims to develop an early appreciation of computational thinking and coding concepts—through simple visual programming.

While the number of content descriptors for the Digital Technologies subject in Australia is proposed to grow by 65%, coding/programming will decline from 14% to 8% of these. This proportional decline is in contrast to curricula in competing countries. For example, 27% of England's Computing attainment targets relate to coding, and 28% of progress outcome sentences in New Zealand involve programming.

In the New Zealand curriculum [5], coding is referred to as creating a 'Digital Outcome'. Reading through the supporting documentation to understand what this is, we find these kinds of explanations:

- Data management software like Filemaker Pro, Access or MySQL would be appropriate for this standard.
- Students iteratively develop, trial, and improve components in order to develop an increasingly refined outcome. During the development process, students are expected to describe and address relevant implications.
- The digital outcome must have been developed by the student.

It is not clear that creating a digital outcome necessarily implies writing code: however, it is also clear that doing so is one such method. The proportion of direct coding content in various national curricula can be seen in Table 2. It is clear there is no commonality in respect of the age at which coding should begin to be learned. There is also a range of coding proportions, even given the non-congruent age ranges.

Table 2. Proportions of direct coding in informatics/computing/digital technologies curricula

Country	Curriculum subject	Proportion of direct coding content
Australia (proposed)	Digital Technologies [F-8]	8%
Australia (current)	Digital Technologies [F-8]	14%
Singapore [6]	Computer Applications [Secondary 1–4]	17%
India [7]	ICT [Years 6–8]	18%
England [8]	Computing [Years 1–11]	27%
New Zealand	Technology – Digital Technologies [Years 1–13]	28%

For Australia, we believe there is an increased need for a foundation on computational thinking and coding at all levels, especially the upper junior, middle, and senior school curriculum. The current Digital Technologies subject shows a greater emphasis on teaching computational and programming/coding concepts in the higher junior school years. However, this decreases in the middle and senior school. We believe it should be similar across all ages of learning.

The Australian Digital Technologies curriculum also highlights, via the content descriptors for each stage, a significant mismatch. Teachers in the junior school who are not trained in programming, have more to deliver in this aspect compared to the specialist Digital Technologies teachers in the senior school, yet are required to be highly trained in this coding skill.

3 Views of Pre-service Teachers

Here are some considered opinions from a tutor of pre-service teachers who had nearly completed a unit on Digital Technologies when the public consultation draft for the reviewed curriculum was released. As previously mentioned, one of the authors was a Digital Technologies Education tutor. In the tutorial group, one pre-service teacher aimed to become a specialist computing teacher; half had a teacher parent or worked in a school; but none had attended a school placement because of Covid-19.

The tutor felt these pre-service teachers were ambivalent about ICT because priority had previously been given to the teaching of literacy, numeracy and science/inquiry. Although inquiry, deep and critical thinking could be promoted by teaching coding, Digital Technologies was not taught to them in school, and so was foreign to their thinking.

Through the informal discussions, the tutor formed three clear ideas about the proposed new curriculum for Digital Technologies. These concerned granularity – number & complexity of content descriptors; language – tension between clarity/specificity and abstraction/ambiguity; and year-on-year progression.

3.1 Granularity

When comparing the original curriculum with the proposed update, some content descriptors have been replaced by two. This change multiplies the total number of content descriptors, but generally splits complex learning activities into separate, more clearly defined activities. An example is shown in Table 3.

Table 3. Split content descriptor example, with distinction between pre-school and Years 1–2

Original	Recognise and explore digital systems (hardware and software components) for a purpose [Foundation to Year 2]
Proposed	Recognise and explore digital systems (hardware and software) and how they can be used to solve simple problems [Foundation/pre-school]
	Identify and explore digital systems and their components for a purpose [Years 1–2]

The original content descriptor has been segregated into two sub-components (see Table 4). While the split retained the essence of the original content descriptor, the distinction between Foundation and years 1 and 2 is an improvement because younger children need to have more specific content descriptors.

Table 4. Another split content descriptor – using more specific language

Original	Examine how whole numbers are used to represent all data in digital systems [Years 5–6]
Proposed	Explain how digital systems represent all data using numbers
	Explore how data can be represented by off and on states (zeros and ones in binary)

The proposed changes to the curriculum appeared to have reduced ambiguity, but not removed it entirely. Splitting an original content descriptor added clarity by breaking the topic into easy digestible parts. Table 5 shows use of specific language such as 'off and on – zeroes and ones in binary' made more sense than using the phrase 'whole numbers.' This leads onto a consideration of the language used in the proposed curriculum revision.

3.2 Language

In some cases, content descriptors in the revision have been re-written using different language (for example, shown in Table 5).

Table 5. A re-written content descriptor, to provide assistance for early career teachers

Original	Recognise different types of data and explore how the same data can be represented in different ways [Years 3–4]
Proposed	Recognise different types of data and explore how the same data can be represented differently depending upon the purpose

With a small change in the language, the revised content descriptor provides greater clarity. The proposed descriptor is more specific and would assist the teacher. Young teachers about to begin their careers would face a lot of uncertainties. If the curriculum was made more specific like this, they would have one less thing to worry about.

In other parts of the proposal, some new terms are introduced. 'User stories' occur in several content descriptors, but are not defined, which is a difficulty. In a couple more, students 'co-construct' products, which is a positive aspect of the proposal, leading to greater learner engagement.

3.3 Year-On-Year Progression

In some ways, the curriculum change had a mixed level of applicability. While some strands such as Collaborating and Managing had increased clarity for the lower years, the content descriptors had become less clear and briefer. Some sub-strands would not be applicable to science and maths teachers as they focused too much on programming, requiring dedicated lessons.

In respect of increased granularity, it was the tutor's opinion that some pre-service teachers perceived scope to build the digital curriculum around a spiral – giving children the advantage of linking back into foundational learning as they progressed towards deeper learning on the same topic.

To conclude, the tutor felt pre-service teachers who were going to teach lower grades felt better about the revised curriculum as it gave them more guidance. Pre-service teachers who were preparing to teach senior grades found the revised curriculum vague. While this is not a comprehensive approach to gauging the value of the revised curriculum, it nonetheless gives us a brief glimpse into the minds of pre-service teachers.

4 Discussion

4.1 Responding to the Research Questions

This discussion is framed around the three research questions posed at the start of this article. The first question addresses the tension between the general ICT capability and the discrete Digital Technologies subject. The proposed curriculum revision perpetuates both aspects but renames the former as Digital Literacy. There are some changes, such as the increased focus on cyber-safety in this general capability, but there is still some overlap in the areas of intellectual property and digital ethics. Unlike other countries which have abandoned the general IT skills aspects, Australia will continue to run both curriculum components. The renaming could accentuate pre-existing confusion between them, which could become a problem. Overall, there is hope that the new Digital Literacies capability and Digital Technologies subject will be more useful than their predecessors. However, the similar names are expected to exacerbate continuing confusion of these different aspects of student computer use.

Other countries have solved this issue by writing appropriate software tools into each subject curriculum and eliminating the ICT/Digital Literacy capability. This is beginning to happen in Australia, for example, dynamic geometric software is required in Mathematics at several Year levels. Another approach is to see that digital technology fundamentally changes the curriculum (for instance, there are no positive online translation skills embedded in the Languages subjects). However, it seems Australia is not yet at this point of curriculum transformation.

The second question looks at the place of programming or coding in the Australian Digital Technologies subject. Whereas other countries have over a quarter of their subject devoted to this topic, Australia proposes to diminish this from 14% to less than 10% of the subject. Curriculum designers appear to fear the explicit mention of programming/coding in the antipodes, masking this skill with terms such as 'create a digital solution' or 'digital outcome'. These very nebulous phrases may resonate with a teaching workforce largely untrained in coding, but also generate diverse alternatives which may not generate the meta-cognition implicit in programming. While the current authors shy away from multitudes of coding languages in schools, some diversity, clarity and logically conceptualised problem-solving culminating in coding can be seen as good preparation for active citizens.

Finally, our tutor discussions with pre-service teachers have highlighted tensions between granularity, language and progression. Teachers will feel comfortable in delivering good education if these issues can be resolved.

4.2 Responding to the Symposium Focus Points

This analysis from Australia sheds some useful light onto the four focus points of the symposium. The first focus point was on the impetus for informatics/computer science curricula specifications. As we have shown, the Review in Australia has led to greater granularity and clarity of language in the curriculum. Looking deeper, the reasons for actually having a Digital Technologies subject in the school curriculum is more complex. Day-to-day computer consumption/use by students was encapsulated by the ICT/Digital Literacies general capability at an early stage of the nationally developed curriculum. The more specialised and creative teaching of digital solutions resonates with economic rationales. While ICT/Digital Literacy contribute to greater gross domestic product, knowledge economies depend far more on digital innovation. The stated rationale for the Digital Technologies subject opens with: "*In a world that is increasingly digitised and automated, it is critical to the strength and sustainability of the economy, the environment and society that digital solutions are purposefully designed to include user empowerment, autonomy and accountability"*.

This rationale accords with OECD economic imperatives [9] to prepare citizens for participation in the knowledge society, and to become innovative creators for it. The rationale however goes further, incorporating environmental and social benefits. Finally, the rationale exhorts student personal achievement and responsibility.

The second question in the symposium enquires about student learning in this Informatics/Computer Science/Digital Technologies subject. Two observations can be made in the light of the Australian experience. At this stage, direct focus on programming is deprecated compared to curricula in other countries, with less than 8% of curriculum content descriptors related to coding. Instead, students use computer-based tools to create digital solutions. This is rather vague, but a lot of computer science skills and understandings are woven into the curriculum. The other observation that can be made is that coding instruction commences at age 9 (Years 3–4) with visual coding, and progresses to a general-purpose language at age 13 (Years 7–8). Object-oriented languages are optionally taught at age 15 (Years 9–10).

The third question asks about the incorporation of innovations such as artificial intelligence and machine learning into the curriculum. Many of these fall into the realm of non-deterministic computing. There are two issues to be considered: learning resources and teacher professional development. International companies have made some excellent learning resources for machine learning [10] and quantum computing freely available [11]. The Australian curriculum provides about 7 examples where students can engage with the use of artificial intelligence systems, but only one where they would work directly with such a system: "*…exploring artificial intelligence data* *analysis where an algorithm is trained by a structured dataset, for example, engaging with online machine learning examples (AC9TDI10P02_E2) [Year 10]".*

The final symposium question about the relationship between the Digital Technologies subject and the use of computers across the curriculum has already been answered. In brief, the relationship is one in tension, and fraught with misunderstandings by teachers, schools, students and parents.

5 Conclusion

The revised curriculum is due to be implemented from the start of 2022. Given the scope of changes to the use of computers in class, a great deal of communication and teacher training will be required.

The proposed revision to the Australian Digital Technologies subject appears to embed the rapidly changing nature of Information Technology. However, there is little mention of non-deterministic programming. Given recent government funding initiatives, artificial intelligence/machine learning and quantum computing might well be included in the Year 9–10 curriculum. The three take-home messages from this analysis are:

a) To what extent should the Informatics/Computing/Digital Technologies curriculum specification in each country be atomised? Greater detail can assist teachers with weaker content knowledge in the subject. Fewer specifications are inevitably phrased using more general language, which may facilitate innovation adoption.
b) The extent to which coding/programming is addressed in the subject is contested. Australia proposes to have a relatively small proportion of learning explicitly focused on coding (8%), which contrasts with the 25% or more in other countries. Perhaps an intermediate level is more appropriate?
c) Countries appear to differ in the framing of general ICT capabilities and dedicated Informatics/Computing/Digital Technologies subjects. Having both aspects in the Australian Curriculum seems to be confusing to teachers, but apparently will be a feature for the next five years.

As a final note of personal opinion, some pre-service teachers in our careers have submitted draft lesson plans for assessment, expecting school students to code with up to three languages in a single session. Understandably, these trainees are keen to demonstrate their capacity, knowledge and agility, but it does put a focus on how much coding is enough. The authors consider a maximum of four computer languages over the ages 5–16 should be sufficient, with only one taught in any year. This would provide practical experience to consolidate the other computational thinking skills acquired. Also, bearing in mind the Sapir-Whorf linguistic relativity hypothesis [12] that your language determines your thinking, these coding languages should have varied characteristics. Current curricula often portray computers as von Neuman uniprocessors or Turing machines programmed procedurally within an algorithmic paradigm. Machine learning, object-orientation and quantum scoring illustrate more parallel problem-solving processes which we believe should be part of each citizen's understanding of information technology.

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Development of IPSJ Data Science Curriculum Standard

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Abstract. The Information Processing Society of Japan (IPSJ) published a curriculum standard for university-level education majoring in data science (DS) (An English translation of the IPSJ Data Science Curriculum Standard is available at: https://www.ipthree.org/wp-content/uploads/IPSJ-DS-Curriculum_202104_en.pdf). In this paper, we shall report strategy and development of the DS curriculum standards. Data science education and the development of data scientists are recognised to be quite important in both social and business contexts. The IPSJ DS curriculum standard is developed by integrating various related initiatives and has the following unique features. (1) The DS curriculum standard covers a wide range of related fields to ensure international compatibility through mapping to the ACM Data Science curriculum and the European EDISON Data Science Framework. (2) It collaborates with the IPSJ Data Scientist certification (under development) by referring to the Data Scientist skill checklist (assistant level) developed by the Data Scientist Society of Japan. (3) It clarifies the knowledge and skills required of students majoring in data science. (4) It assigns a time to each educational content so that the curriculum size becomes approximately 675 class hours (60 credits in the Japanese credit system). (5) It collaborates with the Model Curriculum for Mathematics, Data Science and AI Education (literacy level) developed by the Japan Inter-University Consortium for Mathematics and Data Science, supported by the Japanese government.

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1 Introduction

Various initiatives, such as [1] in Japan, are promoted around the world to develop curriculum standards and professional certification schemes in the field of data science (DS). In this context, the Information Processing Society of Japan (IPSJ) intends to contribute to the development of systematic data science education from the standpoint of both the academic and professional community of computing discipline in Japan.

IPSJ has developed curriculum standards for computing education at the university level for nearly 30 years and has promoted a variety of activities related to computing education at the primary, secondary, high school, and university levels. The J17 curriculum standard [2] was supported by the Ministry of Education of Japan (MEXT). But as of FY2017, IPSJ could not publish a curriculum standard for the DS domain.

However, as of the end of FY2019, various efforts are in progress on curriculum standards in the DS domain in the United States, Japan, and Europe so that standardisation to ensure international compatibility is coming into view. Furthermore, IPSJ is working on the development of a data scientist (DS) certification scheme. IPSJ recently published its strategy for data science and intends to create collaboration between the DS certification and the DS curriculum [3].

Observing the above situation, IPSJ developed a curriculum standard for college students majoring in data science from the viewpoint of computing discipline. Although the Japan Inter-University Consortium for Mathematics & Data Science [4] published two model curriculums [5] in the data science field, the model curriculums do not cover expert level. Compared with other efforts in DS curriculum development, there are significant differences between the IPSJ DS curriculum and other DS curriculums. The major differences are listed below.

(1) IPSJ DS curriculum covers a wide range of related fields to ensure international compatibility by integrating the ACM Data Science curriculum [6] and the European EDISON Data Science Framework [7].
(2) IPSJ DS curriculum is in collaboration with the IPSJ Data Scientist certification (under development) by referring to the Data Scientist (DS) skill checklist [8] (assistant level) developed by the Japan Data Scientist Society.
(3) IPSJ DS curriculum assigns time to the educational contents so that the curriculum size becomes approximately 675 class hours (60 credits in the Japanese credit system).
(4) IPSJ DS curriculum regards the model curriculum as a prerequisite since the model curriculum is designed to teach data science literacy to all college students and its size is much smaller than the IPSJ DS curriculum.

IPSJ DS curriculum is intended to be used as a reference by universities and undergraduate level professional education programmes majoring in data science.

This paper is organised as follows. We shall overview the representative work related to our DS curriculum standard in Sect. 2. EDISON Data Science Framework, ACM Data Science Curricula, and Data Scientist Skill Checklist will be introduced. The development policy of the IPSJ DS curriculum will be explained in Sect. 3. We have three major policies. The first one is the integration of classification criteria of the related BOK and skill set. The second one is the assignment of time to each educational topic. The third one is the adjustment of the contents considering the allocated time restriction. Our effort related to these policies will be explained in Sects. 4 to 6 respectively. In the last section, we shall conclude the paper with an explanation of our vision to implement systematic development and evaluation system of the data scientists of various levels.

2 Related Works

Many efforts are in progress in the DS field. Many DS programmes and seminars are provided by many universities and companies. Target students/engineers and levels are quite diverse among these programmes and seminars. Development of curriculum and body of knowledge (BOK) is essential in the DS field to provide systematic education programmes and seminars for recurrent education. We shall introduce three major works which we refer to develop the IPSJ DS curriculum standard.

2.1 EDISON Data Science Framework [7]

The EDISON Data Science Framework defines DS-BoK as a set of DS knowledge areas (KA) through the analysis of various BOKs related to data science. The EDISON DS Framework also contains DS Model Curriculum and assigns ECTS (European Credit Transfer and Accumulation System) to each KA as represented in Table 1.

Although the EDISON Framework does not provide further detail of the topics at each KA, it covers a wide area of the related fields. Thus, we shall utilise the KAs and the assigned ECTS in developing the IPSJ DS curriculum since DS has an interdisciplinary nature.

2.2 ACM Data Science Curriculum [6]

ACM Data Science Task Force announced the final report of “Computing Competencies for Undergraduate Data Science Curricula” in January 2021. Different from the EDISON DS-BoK, the educational contents are described in detail. Furthermore, the curriculum defines the priority of each content using T1, T2, and E. T1 stands for mandatory content, while T2 represents semi-mandatory content with 80% of the enrollment. E stands for elective content with 50% of the expected enrollment. This information is utilised to develop the IPSJ DS curriculum standard.

On the other hand, the ACM DS curriculum does not contain certain important KAs such as mathematics, statistics, modeling and simulation, and business fundamentals. Thus, we shall add these KAs to our DS curriculum.

Table 1. Organisation of EDISON DS-BoK and assigned ECTS.

KA groups	KA#	DS knowledge areas	ECTS
Data Science Analysis	KA01.01	Statistical methods for data analysis	13.2
	KA01.02	Machine Learning	19.4
	KA01.03	Data Mining	9.7
	KA01.04	Text Data Mining	7.9
	KA01.05	Predictive Analysis	14.6
	KA01.06	Computational modeling, simulation and optimisation	9.4
Data Science Engineering	KA02.01	Big Data Infrastructure and Technologies	8.4
	KA02.02	Infrastructure and platforms for Data Science applications	14.0
	KA02.03	Cloud Computing technologies for Big Data and Data Analytics	12.5
	KA02.04	Data and Applications security	4.6
	KA02.05	Big Data systems organisation and engineering	15.5
	KA02.06	Data Science (Big Data) applications design	15.5
	KA02.07	Information systems (to support data driven decision making)	11.3

We assign a sequence number (SEQ#) to each topic to define the mapping between the ACM DS curriculum and our DS curriculum. The prefix of the SEQ# corresponds to each KA defined in the ACM DS curriculum.

2.3 Data Scientist Skill Checklist [8]

The Japan Data Scientists Society first published the Data Scientist Skill Checklist (DS Skill Checklist) in November 2015, which defines the set of skills required for three levels of the data scientists. In June 2017, the DS Skill Checklist was fully adopted in the ITSS+ (DS domain) developed by the Information-Technology Promotion Agency (IPA), which is a governmental agency governed by the Ministry of Trade and Industry (METI) of Japan. The DS skill checklist is revised every two years and the latest version was published in October 2019.

The DS skill checklist classifies data scientists into three levels: Assistant, Full, and Senior Data Scientist Levels. Each level roughly corresponds to ITSS (IT Skill Standards [9]) levels 3 to 5, which corresponds to SFIA levels 4 to 6 [10] respectively.

The DS skill checklist defines essential skills and other skills at each level. A data scientist is evaluated at a certain level by satisfying all essential skills and a specific percentage of all skills (assistant level 70%, full level 60%, senior level 50%). Table 2 illustrates the organisation of the checklist.

The DS Skill Checklist is developed from the viewpoint of business and covers detailed skills of the KA's which are missing in the ACM DS curriculum. Thus, we shall integrate the DS Skill Checklist and the ACM DS curriculum to fully cover the EDISON DS-BoK.

Table 2. Organisation of the Data Scientist Skill Checklist.

Category	Subcategories
Data Engineering	IT Security, Data Processing, Data Sharing, Data Structure, Data collection, Data storage, Programming, Environment construction
Data Science	Graphical Models, Grouping, Sampling, Simulation, Data assimilation, Data understanding/validation, Data processing, Data visualisation, Pattern discovery, Connotation extraction & insight, Speech/music processing, Image/video processing, Basic mathematics, Machine learning techniques, Testing/decision making, Language Processing, Optimisation, Time series analysis, Understanding properties/relationships, Analysis process, Prediction(<-Forecasting)
Business Fundamentals	Data Acquisition, Understanding data from a business perspective, Problem definition, Activity Management, Contracts and Rights Protection, Code of Conduct, Business Implementation, Conception and Design, Analysis and evaluation, Logical thinking

3 Curriculum Development Policy

The development policy of the IPSJ DS curriculum is defined in this section. Each of the previous works introduced in Sect. 2 has its limitations explained in the section. We shall overcome these problems by integrating these three works. We shall mainly discuss the intention of each policy in this section. Implementation of the major policies will be explained in the succeeding sections.

A) Covers a Wide Area of Data Science to Ensure International Compatibility
DS is considered multidisciplinary since various existing areas are related to DS. Some of them are statistics, artificial intelligence, machine learning, data engineering, business analysis, and security and privacy as can be observed in EDISON DS-BoK. ACM DS curriculum and DS Skill checklist cover only a part of DS-BoK so that both are required to cover DS-BoK.

Furthermore, different KAs are used in the ACM DS curriculum and DS Skill checklist due to their different viewpoints so that integration of the classification criteria is necessary. Thus, IPSJ utilises the organisation of DS-BoK with some modification to reduce the hierarchy of the KAs. The detail will be explained in Sect. 4.

B) Collaboration with IPSJ Data Scientist Certification (Under Development)
IPSJ is currently developing a certification scheme to recognise the ability of data scientists. The certification scheme is based on the DS Skill Checklist since it is approved by a governmental agency (IPA) and is widely accepted among Japanese IT companies. The DS Skill Checklist defines three levels of the data scientist. IPSJ is planning to provide two, assistant and full, levels of the data scientist among them.

When we developed our DS curriculum, we selected the DS Skill Checklist of the assistant level since the DS curriculum is prepared for undergraduate students. There are also many DS seminars in the Japanese industry that reference the DS Skill Checklist of the assistant or the full levels. Utilisation of the topics at the assistant level from the DS Skills Checklist will be useful to develop a unified system to develop and evaluate data scientists in academia and industry in Japan.

C) Specify the Knowledge and Skills Required of the Students Majoring in DS
Although EDISON DS-BoK covers a wide range of data science areas, it only specifies the required knowledge and skills abstractly. Thus, we shall utilise the ACM Data Science curriculum and the DS Skills Checklist to specify them concretely. The topics derived from the ACM DS curriculum are assigned serial numbers beginning with "ACM" in the IPSJ DS curriculum standard, while the topics originated from the DS Skills Checklist are numbered with a serial number beginning with "DS". All other topics are assigned serial numbers beginning with "IPSJ".

D) The Size of the IPSJ DS Curriculum is Approximately 675 Class Hours (60 Credits in the Japanese Credit System
More than 124 credits are required to graduate from university in Japan. A student can typically earn 2 credits by taking 90-min class 15 times (22.5 class hours). IPSJ commonly assigns 60 credits to develop a curriculum standard for undergraduate majored in some computing disciplines such as CS, CE, SE, IS, and IT. We shall also adopt this policy in developing our DS curriculum standard.

At a typical Japanese university, 20–30 credits are assigned to general education for all undergraduate students regardless of their major subject. Approximately 10 credits are assigned for the graduation research project. Thus 85–95 credits can be assigned to the education for the major subject. Considering the diversity of the education programme, it is realistic to leave a certain amount of room to utilise the characteristics of each educational programme.

We shall explain the details of the time assigned to the topics contained in the IPSJ DS curriculum in Sect. 5. When we assign a specific time to each topic, we need to adjust the contents of the topic so that we can teach the topic within the assigned time constraints. The detail of the adjustment will be described in Sect. 6.

E) Students are Assumed to Have Studied the Model Curriculum in Mathematics, Data Science, and AI (Literacy Level)
The Model Curriculum for Mathematics, Data Science and AI Education (Literacy) [5] is developed by the Japan Consortium for Strengthening Bases for Mathematics and Data Science education and is authorised by the Ministry of Education (MEXT) of Japan. Since all university students are expected to learn the model curriculum, the model curriculum is considered a prerequisite of the IPSJ DS curriculum standard.

Thus, no time will be assigned for the topics included in the model curriculum.

4 Integrating Classification Criteria

We shall integrate classification criteria of the ACM DS curriculum and DS skill checklist utilising EDISON DS-BoK in this section since EDISON DS-BoK covers the broadest areas.

4.1 General Principle

The integrated KA has two levels represented in Table 3. The integrated KA also utilises the classification of the ACM DS curriculum as well as EDISON DS-BoK to balance the number of topics at each subcategory.

We define a mapping between the IPSJ DS KA's and the three KA's defined in Sect. 2. We also assign SEQ# to each topic of the IPSJ DS curriculum standard. A SEQ# beginning "ACM" and "DS" respectively represents a topic originated from the ACM DS curriculum or DS Skill Checklist, while a SEQ# beginning "IPSJ" represents a topic added by IPSJ. We also confirm that the IPSJ DS KA system covers the ACM DS curriculum and DS Skill Checklist by assigning the SEQ#.

4.2 Individual Considerations

38 topics are assigned to category A, which are related to the mathematical basis for data science and AI. It is assumed that students have taken Mathematics I, which is a compulsory course in the Japanese high school curriculum guidelines, and the model curriculum (literacy level) established by the Japan Inter-University Consortium for Mathematics and Data Science Education, but is not assumed that students have taken Mathematics II, III, A, B or more, In other words, students are not supposed to have learned exponential and logarithmic functions, differential and integral calculus, vectors, and matrices. Therefore, each school needs to discard related topics according to its admission policy.

Regarding Category B2, Artificial Intelligence, we put topics in that category based on the ACM Data Science Curricula, though some may suggest Artificial Intelligence should entail a wider/narrower range of topics.

Category C contains 44 topics, including two DS Knowledge Areas of EDISON DS-BoK: "Predictive Analytics (KA01.05: 11 topics)" and "Computational modeling, simulation and optimisation (KA01.06: 33 topics)". And it contains subcategories of the "Data Science" category in the Data Scientist Skill Checklist, such as Prediction, Understanding properties/relationships, Sampling, Data visualisation, Analysis process, Data understanding/validation, Connotation extraction & insight, Time series analysis, Language Processing, and Image/video processing. However, there are no corresponding topics in the ACM DS curriculum.

Categories G1 to G3 cover the following topics:

1. Identification of business challenges; gathering, storing, processing, and sharing data; understanding data from a business perspective
2. Building operating environments, planning systems
3. Codes of conduct (data ethics, compliance), activity management, contracts, protection of rights
4. Logical thinking, application in business

The ACM curriculum focuses mainly on teaching technical aspects, whereas the Japan Data Scientist Society's skills checklist focuses more on displaying the skills required in business. The differences between the two are particularly conspicuous.

Table 3. Organisation of the IPSJ data science knowledge areas.

Top level category	Subcategories
A: Basic Mathematics and Mathematical Statistics	1. Basic Linear Algebra, 2. Differential and Integral Calculus, 3. Mathematical Statistics
B1: Data Mining	1. Similarity Measures, 2. Data Preparation, 3. Information Extraction, 4. Cluster Analysis, 5. Classification and Regression, 6. Pattern Mining, 7. Outlier Detection, 8. Time Series Data, 9. Web Data Mining
B2: Artificial Intelligence	1. General, 2. Knowledge Representation and Reasoning (Logic-Based Models), 3. Knowledge Representation and Reasoning (Probability-Based Models), 4. Planning and Search Strategy
B3: Machine Learning	1. General, 2. Supervised Learning, 3. Unsupervised Learning, 4. Mixed Methods, 5. Deep Learning
C: Modeling and Simulation	1. Sampling, 2. Data Visualisation, 3. Analysis Process, 4. Data Understanding and Verification, 5. Language Processing, 6. Image and Video Processing
D1: Fundamental Computer Science	1. Basic Computer Architecture, 2. Storage System Basics, 3. Operating System Basics, 4. File System, 5. Network, 6. Web and Web Programming, 7. Compilers and Interpreters, 8. Algorithmic Thinking and Problem Solving, 9. Algorithms, 10. Data Structures, 11. Programming, 12. Numerical Computation
D2: Big Data System	1. Challenges Associated with Scale, 2. Computer Architecture to Handle Big Data, 3. Parallel Computing Framework, 4. Distributed Data Storage, 5. Parallel Programming, 6. Big Data Application Development Technology, 7. Cloud Computing, 8. Complexity Theory, 9. Software Support for Big Data Applications
E1: Security and Privacy	1. Security Basics, 2. Privacy Protection, 3. Data Security, 4. Data Consistency, 5. Security Analysis
E2: Human-Computer Interaction	1. General
F: Software Engineering	1. Software Design and Development, 2. Software Testing, 3. Collaboration with Related Domains
G1: Data Collection, Management, and Governance	1. Database Basics, 2. Data Collection, 3. Data Processing, 4. Data Sharing, 5. Data Storage, 6. System Operation, 7. Data Management, 8. Information Retrieval
G2: Professionalism	1. Continuing Professional Development, 2. Communication, 3. Teamwork, 4. Economic Issues, 5. Privacy and Confidentiality, 6. Ethical Issues, 7. Legal Issues, 8. Intellectual Property, 9. Automation
G3: Business Fundamentals	1. Logical Thinking, 2. Project Management, 3. Business Implementation

By integrating the two curriculums into our curriculum, we have been able to show how the knowledge, skills, and dispositions in the ACM curriculum are applied in business. If students can learn, through education, to bridge the gap between theory and practice, we will have succeeded in achieving the goals of this category. In terms of educational methods, we recommend providing business case studies alongside theory, using practical exercises as opportunities to discuss ways of applying knowledge, and evaluating the ethical aspects of handling data from a business perspective. Such education should also motivate students to study DS.

5 Assigning Education Time

We assign education time to each topic in the IPSJ DS curriculum standard. The general principle and the individual effort are explained in this section.

5.1 General Principle

The EDISON Data Science Model Curriculum (MC-DS) contains the assignment of ECTS credit points for the BSc programme for major DS-BoK knowledge areas as represented in Table 1. We assign the education time to each IPSJ KA so that the assigned time is proportional to the ECTS points to the corresponding KA of the DS-BoK. The assigned education time is represented in Table 4. Since MC-DS does not provide assignments to the three categories G1, G2 and G3, we assign 112.5 h to these categories considering the balance to the other categories.

The hours for each KA are divided into three categories: T1, T2, and E. The definitions of T1, T2 and E are the same as the ACM DS Curriculum.

The IPSJ DS curriculum is designed so that the effective teaching time is approximately 675 h (60 credits $\times$ 11.25 h/credit), where the effective teaching time is the sum of the number of hours allocated to each teaching topic multiplied by the completion rate defined for the three categories.

The Japan Data Scientist Society assigns the education time for the topics belonging to the DS Skill Checklist. They assigned a time based on their experience at data science seminars for business persons. A total of 180 h is assigned to the topics derived from the DS Skill Checklist, which is 26.7% of the education time of the IPSJ DS curriculum.

When allocating education time for ACM education topics, the time allocated for skill topics should be approximately two to three times the time allocated for knowledge topics. The time allocated for attitude topics will be decided by the team in charge after considering the time allocated for knowledge and skills.

5.2 Individual Considerations

The three categories B1, B2 and B3 are assigned 135, 72, and 117 topics respectively. As the numbers of topics are big, we simply divided the allocated time of each top-level category by the number of topics of the corresponding category. Since the allocated time for some of the topics is very small for its content, we recommend that any

Table 4. Top-level categories and assigned time.

Top level category	Assigned time (h)				Effective time (h)
	T1	T2	E	Total	
A: Mathematical Fundamentals and Statistics	18.25		19.00	37.25	27.75
B1: Data Mining	28.00	36.00	78.00	142.00	95.80
B2: Artificial Intelligence	3.25	17.00	12.50	32.75	23.10
B3: Machine Learning	13.75	19.50	13.50	46.75	36.10
C: Modeling and Simulation	11.80	18.38	47.00	77.18	50.00
D1: Fundamental Computer Science	81.16	22.50	26.25	129.91	112.28
D2: Big Data System	7.00	59.50	47.00	113.50	78.10
E1: Security and Privacy	41.93		4.00	45.93	43.93
E2: Human-Computer Interaction	16.83			16.83	16.83
F: Software Engineering	50.50	25.00	38.00	113.50	89.50
G1: Data Collection, Management and Governance	27.01	25.67	17.00	69.68	56.04
G2: Professionalism	16.14	12.01	7.99	36.14	29.74
G3: Business Fundamentals	10.50		8.33	18.83	14.67
Total	326.12	235.55	318.57	880.24	673.85

potential lecturer or course organiser may want to integrate multiple topics so that they can have a reasonable amount of time to cover them, as it would be usually the case that covering multiple relevant topics would make the lecture more efficient.

Category C was assigned 50 h of effective time (Assigned Time (h) T1: 11.8, T2: 18.38, E: 47.0, Total: 77.18; as shown in Table 4). It was assigned based on "Hours required for education" of corresponding topics in the Data Scientist Skill Checklist. Because, indeed, "Hours required for education" in the Data Scientist Skill Checklist of corresponding topics in Category C was quite shorter than the assigned time proportional to the ECTS points, the assigning education time was adjusted and elongated based on the ECTS points.

The topics initially assigned to Security and Privacy (category E1) come from the ACM DS curriculum and are rather rich and of high level, while the time assigned to information security is limited to 4.6 ECTS in DS-BoK. Thus, we decided to assign 45 h to this area, which corresponds to two classes at a Japanese university.

Although the number of topics belonging to Software Engineering (category F) is not many, the granularity of the topics varies. Some of the topics are simple knowledge, while some topics require extensive software development projects. Thus, we assign 0.5 to 6 h to each topic, taking into account the educational content.

6 Adjusting Educational Contents

The educational contents of each topic depend on the time assigned to the topic so that there is a strong relationship between the decision made in Sects. 5 and 6. We shall summarise the decision to adjust educational contents in this section. We shall mainly explain the differences by focusing on the changes made to the educational content of the original curriculum.

Due to the limitation of assigned time for Security and Privacy (category E1), we assign time only to the topics with T1 priority. Although a data scientist should have sufficient knowledge of security and privacy, a data scientist is not an expert on computer security. The Japanese government provides a certification scheme [11] for computer security professionals based on ISO/IEC 27000 series. A data scientist is expected to collaborate with such security professionals.

There are many descriptions such as "can practice something in all fields" in Software Engineering (category F) of the ACM DS curriculum. We have changed the wording to "can practise something in multiple fields" because it is considered unrealistic considering the assigned time constraints.

We also added the following topics based on the revision plan of SWEBOK 2021: Design patterns for AI and IoT applications, Value creation and proposition, Agile software development practice, and DevOps. However, since the contents of the revision of SWEBOK have not yet been finalised, changes may be made in the future.

7 Conclusion and Future Direction

IPSJ has made the draft DS Curriculum Standards available for public comment and published the DS Curriculum Standard on April 2021 after a minor revision considering the submitted comments and the updates of the ACM DS curriculum.

The educational content of this data science curriculum standard is quite rich, and not many universities can cover all these contents by themselves. However, with the Corona disaster, online education has become popular in universities. The Japanese Standards for the Establishment of Universities have recently been revised to allow multiple universities to collaborate to run a single educational programme. We believe that a combination of online education and university collaboration is quite effective to realise quality assurance of specialised education in data science.

IPSJ is also working to develop a collaboration of college-level education majoring in data science and certification scheme for data scientists in industries. A seamless development and evaluation system are essential for the effective development of data scientists expected to contribute to many aspects of society and business.

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Proof of Concept Teaching for 21st Century Digital Literacy in Portugal: A Pedagogical Approach Towards a New Educational Model

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Abstract. This paper addresses an analysis of contemporary, structured, and connected pedagogical approaches to the teaching of digital proficiency/fluency in 21st-century digital literacy. We present a proof of concept and epistemological valorisation of digital literacy previously underestimated. This epistemological valorisation focuses on teaching digital literacy through understanding how teachers work - pedagogical planning, teacher training, syllabus design, practical work - enabling us to train technology producers instead of passive technology consumers, to enable agents instead of clients. The term "digital" will refer to 21st-century digital literacy. To "think digital" will refer to the mental process carried out by digital natives when conducting operations involving ICT - as their native language and framework. The pedagogical background is paramount to the structures underlying teaching of 21st-century digital literacy, characterised by its disruptive building process achieved through the acknowledgement of epistemological foundations. High school teaching of 21st century digital literacy is by no means at ground zero. The fundamental concepts to be conveyed remain the same: electric coding, input and output devices, memories, processors and transistors – the process/system is just faster and smaller. The development of a proof of concept was built according to a DSR framework, in an iterative way, giving evidence of architecture configuration, an asset of information, of tools, procedures, and attitudes.

Keywords: Pedagogical architecture · Digital teaching · Digital · Pedagogical communication paradigm

1 Context

The former pedagogical approach to the digital society provided high school students with 3 separate stages: electricity, electronics, and coding. Our pedagogical architecture proposal seeks to realign the pedagogical approach to 21st century digital literacy [1] in high school. Learning should be contemporary, structured, and integrate pedagogical structures that introduce concepts, technologies, coding languages, etc. The teaching of

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digital fluency ought to intervene in three different domains: learning spaces, what to teach and how to teach it, and feedback structures. To teach how to be "digital" would be to teach digital fluency – beyond digital usage or digital literacy. Teaching digital fluency in the 21st century requires understanding how technological components work, where they can work and why - not only what they are, or how to use them as mere tools.

This new alignment assumes a heuristic knowledge of the technology and its impact, over mechanical repetitive processes. These might be productive, but will hardly generate knowledge or digital literacy, let alone fluency. The simple development of mechanical skills falls short of the ambitions set for 21st century education. The tacit assumption that the intense/repetitive use of a tool or a method could be a valid pedagogical approach to ICT has proven not to result in digital empowerment. Hence, new strategies and pedagogical approaches are necessary to maintain a connection between users and their perception of how it works, steering them towards real life problem-solving skills. Students must be immersed in experimentation, in construction, and to be able to build their own knowledge using previous stages of acquired knowledge. This pedagogical approach addresses a conceptual redefinition of the learning context and the learning environment - this early stage of the iterative methodology will be described later. This first stage provides proof of concept for the original project [2]. The proposal is originally based on the perception of how 21st century digital skills are taught in high school – the distance between using and functioning is increasingly high.

A computational device can automate processes, but it does not and will not automatise learning. Pedagogy lies not in the computational device nor in its use. Despite an abundant proliferation of various computer support technologies in education, Portugal faces a lack of pedagogical reflection to sustain such proliferation. Despite the introduction of technology in the national education system, and despite the internet being available since the 1980s, most school crystallised in a unidirectional pattern of education: instructions are directed to students lined up in traditional spaces, facing a lecturer-style teacher who replicates concepts, teaching the same to everyone. The introduction of technology did not bring a much-needed disruption to this instructional pattern. Nor did the introduction of psychology techniques or of active methodologies that were only a panoply of platforms or 'apps'. We should point out that the proliferation of computer platforms in education that resulted from the general demand for access to digital communications, for any and all purposes, burdened the schools' administrations in such a way that it reallocated financial resources due to investigation and innovative work, to "feed" administrative requirements. Both focus and educational "energy" steered away from innovation towards administration.

The existence/acquisition of technology is not, contrary to common knowledge, tantamount to innovation or modernisation in secondary education levels. Nor does it lead to a quality education, or a more sustainable organisation. Misguided use of digital hardware and software can be damaging to an organisation should the volume of technological investment not generate knowledge, innovation, or disruption – the lack of epistemological values will be detrimental. Thus, we seek to contribute to an educational enterprise that is reflexive and set on epistemological values, and on contemporary pedagogical approaches that will incorporate the grounds, structures, and development of the conditions to the adequate teaching of 21st century digital literacy.

This pedagogical approach results from identifying the need to reduce the gap between the use of digital tools and the awareness of how they work. This led to the questioning of how to empower students for digital fluency. Should it be through digital skills, or through the improvement of digital proficiency and awareness?

For clarification, when using the term “digital” we refer to the pedagogical architecture being proposed. Terms such as ‘electronic platform’, ‘computers’, ‘robotics’, ‘ICT’, ‘digital application’, ‘digital tools’, ‘platforms’, ‘learning platforms’, ‘new technologies’, Internet, informatics, etc., are often indistinctly used, though they are not interchangeable. Thus, the term “digital” as a noun rather than as an adjective, refers to and includes this entire value chain. “Digital” is assumed as a concept including the spectrum of hardware devices, software, ‘machine learning’, IoT (Internet of Things), Industry 4.0 or even ‘Artificial Intelligence’. It includes, in addition to ‘System and Communications Hardware and Software’, applications of the educational processes it supports, as well as the representation of its relationships with humans. Taking “digital” as a noun in education is also the recognition that more discussion is needed amongst educational experts regarding the ambiguity of the lexicon. “Digital” refers to digital literacy/fluency - the ability to function in the digital world as a native, fluent in the language, capable of using the tools, sufficiently skilled to function with hardware, software, languages, and technologies, and able to create innovation and knowledge.

1.1 Literature

The democratisation of ICT in Portuguese education was always based on national government programmes, consistently introduced in public schools. That first programme – *Minerva* (1985–1995) – was introduced by the Ministry of Education (ME) and overseen by the Planning and Studies Office and the Department of Programming and Financial Management. *Minerva* was developed in articulation with higher education institutions. Programme *Nónio Século XXI* (1996–2002) sought not only to integrate ICT, but also to enforce a series of measures to redesign the national educational system, stimulating new pedagogical practices. The *UARTE* (1997–2003) project, supervised by the Ministry of Science and Technology, sought to provide Internet access to all national primary and secondary, equipping school libraries with a computer and Internet connections. In 2005, the ME created EDUTIC unit as part of the Information and Evaluation Office for the Education System. That same year, all the competences exercised by EDUTIC were transferred to the Computers, Networks, and Internet at School Mission Team. The purpose was to install computers, networks, and *School Internet* – access to the internet in school facilities. The unit designed, developed, implemented, and evaluated mobilising and integrating initiatives in the use computers in the teaching and learning processes. The latest governmental programme for ICT and digital literacy - *Technological Plan for Education (PTE)* began in 2007, and sought school modernisation to create *in situ* spaces of interactivity and knowledge transfer. This was the first programme that focused on the certification of the digital skills of education agents, and on preparing children and young people for the knowledge society. This programme is still active in Portuguese public schools, focusing on the upkeeping and updating of technological assets (Fig. 1).

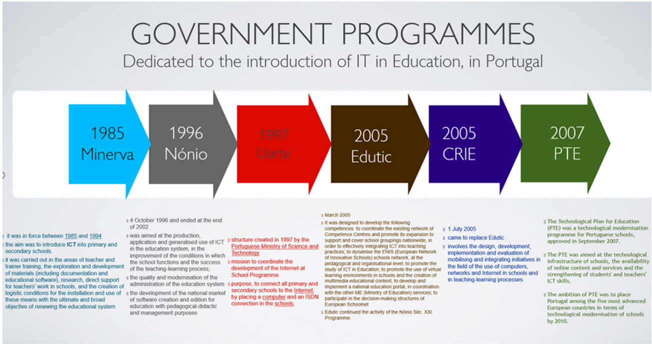

Fig. 1. Temporal introduction of Portuguese digital governmental programmes or education [3]

Since 1985, we can identify three differentiating moments of intervention: Introducing computers at the school (*Minerva* and *Nónio*); Bringing schools on-line – internet connectivity at school facilities (*UARTE*); Hardware maintenance (*PTE*). None of the aforementioned government programmes presented a pedagogical axis, a vision, or a structuring pedagogical design for a true systemic, global and transformational model. Thus, it is necessary to revisit the pedagogical context of continuity and adaptability – how did schools keep up with the EU digital transformation Agenda? [4]. Thus, it is an opportunity to implement the concept of the digital literacy instead of technological skills (an upgrade), and digital literacy instead of mechanical digital skills. Should literacy be set as an educational objective, the particularities of the "digital" should be analysed: how it appeared; how it was built; why was it built; what difficulties were overcome; what successes, failures, challenges, and evolution stages were overcome. Challenges set for students should encourage reflection on their relationship with the digital world and digital knowledge. The inclusion of the relationship between students and the digital world acknowledges the value of a cultural asset common to the communication paradigm [5], information assets, tangible pedagogical assets, and culturally accepted procedures and attitudes [6]. Our pedagogical architecture proposal recommends a feedback structure, following the concepts of John Hattie [7], Paul Black and Dylan William [8], that, deprived of judgement or assessment, seeks to provide support and guidance to students and to the community. These support and guidance functions have a signalling function to support the capture of meanings, so that the action of exploring can make sense within such an architecture. The feedback structure, though sometimes not explicit in its action, is set to underpin verification and improvement.

The digital society influenced everyday life from the 1980s when the computer evolved into its domestic form as the 'Personal Computer' (PC). The computational devices' epistemological foundations led to the need for automated support of human operations (initially only for calculus), and led to a use of automation in the information processing, with concerns about integration and recording of the operations properties considered relevant, to extract valuable information, to extract knowledge. In this evolution the need to put these machines 'talking' with each other also arises. It is through the use of this functionality that a new dimension such as the internet emerges. It is through this potential that phenomena with both positive impacts and negative impacts for humanity are born. The on-going digital impact also increases the demand for digitally literate citizens. Citizens should be able to use digital tools in a wide range of circumstances, and above all, able to adapt flexibly to ever-changing environments and ecosystems, where there are clearly social implications. From a social and cultural perspective, “digital” awareness offers opportunities to transform, create, and innovate. It is in this balance, between knowledge and its interpretation, its questioning and its construction, that it is considered relevant to contemplate teaching digital skills. “Digital”, in this architecture, means deepening the dimension of digital literacy – the relationship with the digital world and 21st century digital skills and its awareness begins in the cradle.

2 Research Plan and Methods

The project that originated this architecture involves the construction of an artefact − a construction for a certain purpose. The purpose of the construction of this artefact is to develop a pedagogical process for teaching 21st century digital literacy − by intervening in the pedagogical components, the teaching/learning environment of teachers' relationship with the praxis, and the learners' relationship with knowledge.

The methodology includes the following points: the creation of a new artefact – development and implementation to redesign practice to achieve the goal – to redesign the traditional pedagogical approach to digital training, shaped towards a true process of creating digital actors – digitally fluent and proficient. The artefact results from inputs from literature and field work. Thus, we believe it stands before a typical ‘DSR’ research scenario [9]. The construction was developed iteratively, and each iteration was evaluated. The re-evaluation of the problem should refine the quality of the design process, each iteration and so on. This building and evaluating cycle is also typical, and happens several times before the final artefact design is considered completed [10]. DSR can be seen as a realisation of three cycles closely related to research activities [11]. A relevance cycle initiates the DSR, in an iterative process with the application context, which not only provides the requirements for the research but also its ‘inputs’. The rigor cycle iterates between the artifact design and the block that provides the knowledge for the project. This was the path followed by this project.

Figure 2 embodies the definitive representation of the methodological framework adopted in this research project. The three constituent blocks of the ‘framework’ stand out, and their adaptation to the reality of this project to the tasks that are part of its construction, as well as the iterative cycles that, along with the moments of evaluation, mark the whole dynamics of the project and promote its relevance and rigor. In a summary of the framework, the cycles represent the dynamics of the research that takes place in the context identified in the ‘Environment’ Block and receives the ‘inputs’ with contribution to innovation from the ‘Knowledge Base’ Block.

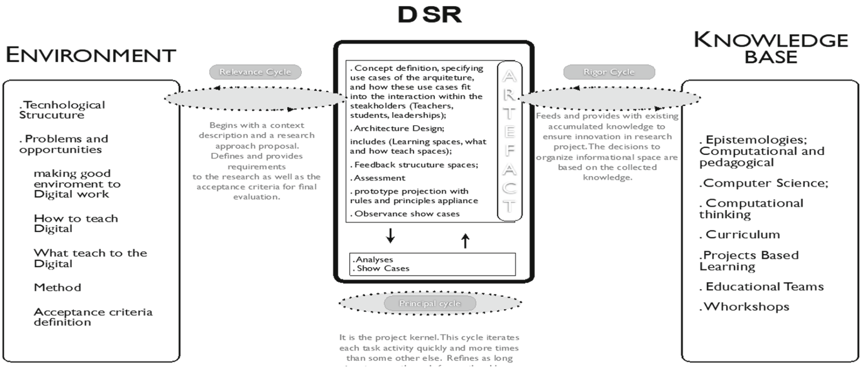

Fig. 2. Methodological framework applied (adapted from Hevner & Chatterjee [11])

The ‘environment’ Block – clearly and precisely characterises the environmental element of this project, represented in this specific sector. It includes the needs and requirements of the project, identifying in the educational environment the relevance in the following areas of application: i) Structure and culture of the organic units or schools, in relation to what is in the focus of the research project – the technological infrastructure made available to the community, as well as the way of teaching and learning digital literacy, and with the digital technologies; ii) Creation of favourable conditions for the smooth running of the implementation. It focuses on the process and on people, and on the conditions available; iii) The characterisation of the acceptance criteria will be revisited in the evaluation phase of the project to dictate or not its success. In an initial phase, from the teaching side, these criteria relate to the functional success of the implementation of the pilot demonstration case. The same happens on the learners’ side, where it is relevant that they go further, autonomously.

The ‘Design Science Research’ Block – the activities of creating, designing, and recording the representation of the implementation proposed in this project. In this block, two groups of tasks are worked on: i) The production of a viable artefact – understood in our project in the form of ‘construction’ and identifying the constituent components for prescriptive implementation, as well as the new ideas sought that serve the intentional purpose of aligning the educational activity in and with digital technologies; ii) Justification and validation of the artefact – The demonstration activity is exercised through demonstration cases and seeks to affirm the viability of the prescription in its usefulness and in its explanation. These cases are produced in real environments – on a school floor and with information produced in the laboratory preparation.

The ‘Knowledge Base’ Block – stores the concepts on which the research is based. These concepts are obtained by collecting information from already developed, evaluated, and mature scientific work (theories, axioms, taxonomies, methods, etc.). It is composed of epistemological foundational work, from which more mature, substantiated and applied knowledge is derived. Some examples are the body of theoretical grounding of algorithmic thinking, the epistemological foundations of pedagogical paradigms or even from computer science principals. This block also includes information collected in the field, from workshops held at different times.

It is important that the elements described above and the iterative way in which the project progresses, strengthen the placement of the work in a 'Design Science' research paradigm. In the faithful execution of this way of research, it is also important that the identification of the iterative work cycles that operate between the blocks presented, make the final implementation presented stronger.

3 Learning Spaces: From a Classroom to a Digital Lab

Physical spaces designed for the teaching and learning of ICT in secondary school have been the subject of study since the year 2000. There is a trend towards studying the transition from the classroom to what are called learning spaces. Some examples: "Learning spaces" [12], "Learning spaces: involving teaching staff to improve pedagogy" [13] and the work "Designing learning spaces" [14]. These works highlight concerns in the interconnection between the physical design of spaces and how it may or may not have impact on the organisation of individuals, on their relationships, and on how teaching and learning take place. The proposal is to upgrade from a mere space to a learning environment.

Our proposal resorts to a teaching and learning space based on the organisational architecture of the inviting classroom project of the 'Future Classroom Lab' [15] - a work resulting from the iTEC project [16]. The configuration in AP_PDF is adapted, with the resources organised to ensure "digital" inception via the teaching and learning process and not to use digital tools as a means to an end – but as an end in itself.

This configuration adds resources that facilitate the connection to the particularities of the "digital", that allows us to deconstruct how they were built, why they were built, and that allows us to present students with the challenges for the construction of new digital solutions. It goes further: it addresses how challenges are being developed step by step, in a pedagogical analysis. Thus, we ensure that inputs on the construction of the space are aligned with educational literacy goals. We suggest the inclusion of some technological and computational equipment to support the afore-mentioned goals applied to the "digital" teaching. The following equipment should include: the 5 components of a PC (Power supply, Motherboard, processor, memories and disks - both Hard & SSD); PCs assembled exposed in their components; Soldering irons, solder, dupont connectors and resistors; Set of Sensors dedicated to educational objectives; Multimeter; SBC (Single Board Computers) with 4-core processors; SDCards of at least 32 GB; LCD monitors, with multiple video inputs (HDMI, DVI and VGA); Wired and wireless keyboards; Wired and wireless mouse.

A way was found to provide the student with equipment and accountability using that equipment that includes kits with the last five items. Each student or group of students take responsibility for, unpack, check, use and pack up again after work. Although digital items are often designated as 'smart' ('smart watches'; 'smart phones'; 'smart cities'), it does not grant these digital technologies with "magical" powers nor does it make them entities, let alone thinking beings. In the learning space we advocate, it is also relevant to understand the value of each item that will support the pedagogical practice - how and when to place them and with which technology (hardware, software and settings) to pair it. These actions should be aligned with the transversal curriculum and have a yearly update. This will allow us to ensure that the classroom is a space of discovery, passion, and joy, see Fig. 3a and b. The technology supports the action, but the planning, the development, the questioning, and the execution of the educational act must also take part – likely a most significant one - in the pedagogical architecture AP_PDF. Only when such premises are fulfilled and students are allowed to enter a space that complies with the patterns set to achieve digital and values students' relationship with knowledge can we grant due value to information, tangible, procedures, and behavioural assets.

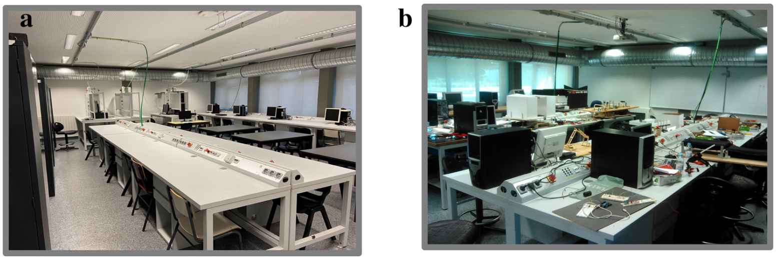

Fig. 3. a) Digital skills classroom and b): Digital immersion space displaying evidence of digital literacy challenges (Fontes Pereira de Melo high school in Porto, Portugal)

4 Educational Structure

4.1 What to Teach and How to Teach It

The disruptive architectural space proposed above for the teaching of digital literacy, values conceptual particularities for student challenges, and combines epistemological justification in the design of the pedagogical innovation plan, in the learning spaces, in relationship with knowledge, and in the feedback iterations for improvement. The proposal we advocate identifies with the movements that propose to grant the "power" of computing and digital production to all those interested (digital democracy) [16]. Syllabus and digital base contents should be designed for contemporary teaching and learning spaces, according to AP_PDF, respecting differentiation, and the singular identity of students. The contents and intellectual challenges are aimed at establishing a relationship with knowledge in ten broad, in-depth points, considered structuring in the relationship with Digital knowledge, namely: (AL) Algorithm; (CS) Computational systems; (MLT) Multimedia; (DIK) Data, information, and knowledge; (DD) Design and Development; (EUT) Effective Use of Tools; (CN) Computer Networks; (P) Programming; (SP) Safety and Protection; (IT) Impact of Technology.

This element of the architecture referring to the relationship with knowledge is designed and adapted to 12 years of compulsory education in Portugal. The first years focus mainly on development of dexterity in digital skills, which helps students to understand how those digital devices, such as a keyboard, work, and what happens when a key is pressed and a letter or a symbol appears on the screen. As students advance in their schooling it will be necessary to introduce the concepts mentioned above. These paths through the pedagogical space of architecture, about what to teach include work in the dimensions of physical devices, in the dimensions of the logical and abstract components, and in the dimensions of their relationships with humans.

Regarding teaching methodologies, we propose conceptual adaptable spaces. Considering that digital literacy is a relatively recent subject in the curriculum, there is little specific scientific-pedagogical work able to illustrate teaching approaches. Given that lack of in-depth pedagogical studies in the area, we propose ten pedagogical principles for teaching digital literacy: Leading with concepts; Leading with error; Real-world activities; Collaborative work; Priority in reading and code exploration; Creation of projects; Physical connections (Hands on); Dismantling misconceptions; Writing texts; Adding variety to activities and challenges.

4.2 The Equipment - Designed to Teach

In this space of architecture, we should mention that a recent piece of equipment has been made available to the educational community - a trend for those who want to develop the relationship with digital knowledge [17]. This equipment is referred to as SBC (Single Board Computer), and is very similar to regular computers. It has, however, a significant physical difference, as this computer has the physical dimensions of a credit card. This equipment allows internet navigation, sending an email, or using any MS Office tool such as a word processor. It is possible to go further as the equipment allows establishing a physical link to electrical or electronic devices, via forty metallic pins included on the SBC board. The device can be programmed to provide or receive electrical impulses. This opens a universe of computational and construction possibilities not available on other desktop, laptop, or tablet computational devices. The low cost (around 70€) device was designed from scratch to teach digital production to youngsters. The SBC works as desktop or laptop, runs on a free and open operating system, and uses a memory card like those in digital cameras or mobile phones. A 'USB' charger of a mobile phone can power the SBC, it can be connected to a 'USB' mouse and keyboard and to a TV or monitor desktop. At school, this equipment can be an asset to teaching and learning, coding, and can help in dozens of other multi-disciplinary activities like science and music, for example.

To validate the viability of the digital literacy pedagogical architecture proposed, we designed and implemented a workshop for teacher training at the Porto Polytechnic Faculty of Education. The workshop design included: the reasons behind the relevance of the workshop (disruption); the target-audience; goals; contents; methods; and assessment. The workshop produced meaningful results – a multitude of strategies to the discovery and implementation of pedagogical approaches.

5 Conclusions

The paper begins with a clarification of the term "digital" to seek broad-acceptance terminology and to dismiss ambiguity. The proposed pedagogical architecture uses dedicated equipment designed for teaching, pedagogical strategies in syntony with prior epistemological assertions, empirical classroom experience in the creation of activities, curriculums mapping, plans, and support materials for teaching digital literacy.

The new ICT classroom proposed is now designed for teaching digital literacy. The current agenda for teaching digital literacy is embodied in a digital transformation policy that seeks greater digital empowerment. This digital empowerment should be achievable by combining digital skills with digital literacy to create a conscious relationship with the digital world. The AP_PDF addresses digital literacy by trying to deepen digital proficiency and awareness by teaching how technology works and not simply how to make use of it.

A disruptive pedagogical architecture might be the solution to achieve the goals set for 21st century digital literacy and break the patterns of traditional secondary education in Portugal. Our approach analysed current pedagogical trends and the contemporary pedagogical paradigm on digital literacy teaching tools and methods. The former paradigm is based on prior learning digital skills as instruments, procedures and attitudes culturally and contextually accepted. We have also analysed how digital literacy training follows a different path as it respects the relationship between form and function of the digital skills, in the teaching and learning process. Disruption of the paradigm emerged on the first stage of the design framework, which revealed that intensive repeated usage does not create knowledge, nor new digital assets, regardless of how new forms of training are adopted, or even how correct they are. Thus, we can assume this as an opportunity to propose the use of the term "digital" as a replacement to ICT, training for digital literacies instead of for digital skills. This opportunity is relevant in primary and secondary education. Considering literacy as an educational objective, the particularities of digital literacy must be considered - how digital reality appeared and how it was built, why was it built, what difficulties it had to assert itself, its successes and failure, challenges and evolution that have taken place. The paradigm disruption for digital literacy can be conveyed from early education by designing adequate learning environments for digital awareness, pedagogical methodologies, and 'feedback' structures that ensure that trial and error are developed in the process.

This pedagogical architecture was designed to generate disruption in the Portuguese ITC teaching culture and induce the migration to the teaching of digital literacy. Digital empowerment requires training students to become digital entrepreneurs instead of digital consumers. By providing disruption in the teaching and learning environments, inducing diversity, nurturing experimentation within the respect for epistemology, our pedagogical architecture proposal for digital literacy education can foster meaningful relationships with the digital society, to enable awareness of both concepts and tools, and a conscious relationship with digital knowledge. Though disruptive indeed, this is a path likely to aggregate digital awareness, technological awareness, and combine both with digital skills to achieve digital literacy.

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Use of *Vclass* in Mathematics Education Delivery: The UEW Experience

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Abstract. The onset of Covid-19 pandemic has compelled institutions of higher learning to experiment with various online learning management modes, in lieu of the traditional face-to-face mode of instruction. However, conclusions about the effectiveness and sustainability of these new learning modes are not well-established. This study explored experiences of mathematics education lecturers and students who were first time users of an online learning management system referred to as *UEW vclass*. The sample comprised 10 students pursuing the degree of Bachelor of Mathematics Education and four lecturers who taught them five different courses at the University of Education Winneba (UEW), Ghana. Data were collected via interviews, and a survey item created on Google forms and administered through WhatsApp pages of respondents. The results of SWOT analysis show that lecturers found the *UEW vclass* useful and amenable to their teaching and assessment practices. As first-time users, the lecturers found the course creation, online delivery and e-assessment practices exciting, though challenging in terms of their digital and pedagogical skillset. Internet connectivity and system errors affected lecturers' real-time lesson delivery sessions while the trustworthiness of e-assessment scores was a serious concern. Students found the *UEW vclass* suitable, convenient, interesting, and user friendly. However, students' challenges were login, network, timing, real-time feedback and typing mathematical symbols. The paper therefore recommends an upgrade of network bandwidth to improve access, a built-in math symbols app, training and orientation of lecturers and students. The hybrid mode of learning is also recommended to enhance learning outcomes.

Keywords: Mathematics · Online experiences · LMS · UEW *vclass*

1 Introduction

The advent of the Covid-19 pandemic has rapidly influenced every domain of human existence and drifted human undertakings to a *new normal* in which social distancing becomes the norm. With the emergence of the new normal, educational institutions worldwide are beset with teaching, assessment and learning sustainability crises [1]. These crises compelled many educational managers and lecturers to rethink mathematics educational access and delivery, while students strive to adjust to new learning

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systems external to the orthodox face-to-face mode. The quest to determine *which* and *how* learning platforms can be used for mathematics educational delivery remains unsettled.

Institutions of higher learning are quickly adapting to the crises. Universities across the world were obliged, after March 2020 lockdowns, to quickly migrate into purely online modes [2]. The people's Republic of China where the Covid-19 first hit, for example, moved fully into online platforms and implemented the "School's Out, But Class's On" policy to promote broad-based online teaching and learning to sustain academic work [3]. Universities in developing countries like Ghana, though unprepared, were also coerced to experiment with various online learning management systems in a bid to continue educational delivery [1, 4]. For example, new and emerging digital learning platforms such as Moodle, Sakai, Zoom, Edmodo, Quipper, Google meet, have been experimented in schools without prior evidences of their effectiveness, successes and shortfalls. For the past one and half years, there has been unprecedented push in Ghana towards online teaching, learning and assessment. Providers of commercial digital learning platforms also rushed to provide support and solutions to educational delivery, sometimes for free. Government of Ghana directives and regular updates of tensions and increasing spread of Covid-19 also obliged universities to sustain the drive towards online learning [1].

The University of Education Winneba (UEW) trains competent professional mathematics teachers for all levels of education in Ghana and the West African subregion. Prior to March 2020, the move to online mathematics instructional delivery was met with resistance due to faculty deficiency in digital pedagogy, low ICT infrastructure and resources, as well as a lack of student support systems. When Ghana recorded its first case of the Covid-19 in March 12, 2020, culminating in lockdowns and closure of all institutions on 16th of March, 2020, the academic calendar was disrupted [4]. UEW was therefore compelled to devise innovative ways of using Learning Management Systems (LMS) to enable students to learn at home amidst the pandemic, to bring the 2019/2020 academic year to a successful close. After some few weeks of experimenting various low cost and open learning sources such as Zoom, WhatsApp, Google class and Telegram, UEW management finally mandated its faculty and students to use the LMS called *vclass* as an official platform for online learning [5].

The UEW *vclass* is a Moodle based platform enhanced with BigBlueButton for live video lecturing which can be recorded, saved and played back online or offline. In the *vclass*, lecturers are given privileges to create and develop courses, upload course materials onto the online platform and subsequently engage students in learning using e-resources such as chats, forum discussions, assignments, quizzes and downloadable materials. All lectures, live videos, study materials and assessment data are stored in UEW server for retrieval. To facilitate its use, UEW ICT directorate provided short time training and hotline support system for faculty to create courses, teach in front of a computer screen and implement e-assessment. Students were also given virtual orientation on how to login to the vclass, enroll for courses, access study materials and participate in lesson delivery and assessment online, while at home. A diagrammatically representation of the UEW *vclass* is shown in Fig. 1.

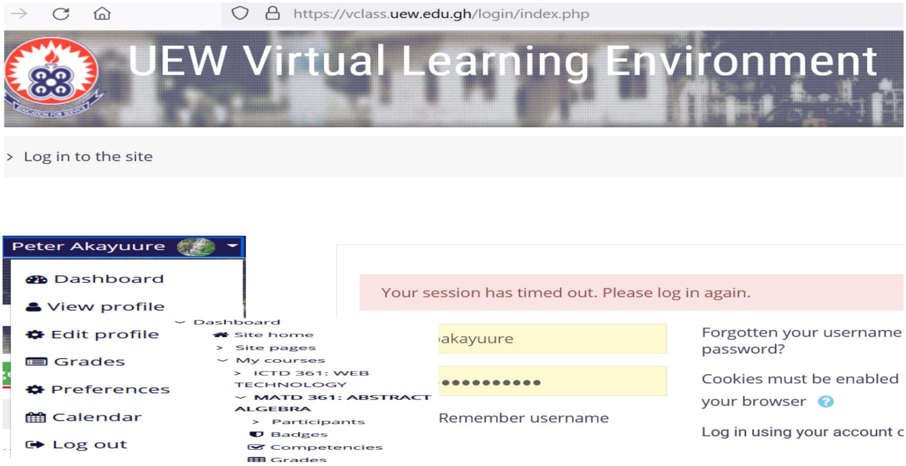

Fig. 1. The interface of the UEW vclass

As a result of the Covid-19 pandemic and digital experiences, UEW plans to emphasise, consolidate and serve as a pace setter of online instructional delivery for its regular, sandwich, and distance modes beyond the Covid-19 era. However, due to the swift and abrupt nature of moving courses online, and as first-time users of the *vclass*, lecturers and students are likely to encounter challenges or discover some potential of the *vclass* [4]. In other words, attempts to sustain this new innovation of using the *UEW vclass* for mathematics education delivery in UEW require an understanding of the new dilemmas and contextual issues regarding ICT infrastructures, faculty capacity, and students' support and welfare. Around the world, researchers and educators are trying to research into the paradigm shift from the face-to-face learning to online education and users' experiences [6]. This is because understanding users' experiences in online learning platforms is crucial to its success and sustainability. This study therefore mirrors students' and their lecturers' experiences in the use of the *UEW vclass* platform to learn various courses in mathematics education in UEW.

The study was guided by the following research questions:

1. How do lecturers and students experience the use of *vclass* to teach and learn mathematics courses?
2. What are the challenges faced by lecturers and their students in using the *vclass* in the teaching and learning of mathematics courses?

It is hoped that this empirical data on how lecturers and their students experience and adjust to the new learning system to meet curriculum requirements would help in decision-making towards improvement and sustainability of *vclass* in UEW. Evidence from this study would also provide first-hand information that would shed light on the strengths, weaknesses, opportunities and threats (SWOT) regarding deployment of emerging digital platforms in mathematics instructional delivery in the Covid-19 pandemic era and beyond, in developing countries such as Ghana.

2 Related Literature

Advances in digital technology have given birth to a new era referred to as the Fourth Industrial Revolution (4IR). The 4IR comprises technology-based tools and digital platforms which are currently transforming the teaching and learning of mathematics. As a result of the Covid-19 global pandemic, there is a growing body of research currently focusing on technology platforms in education [2, 7]. These studies have shown that integrating digital tools in mathematics pedagogy supports learning, and has positive effects on students' mathematics performance. A study by Marpa [7] found that the use of technology in mathematics teaching bears relevance and significance to the mathematics teachers because they develop positive attitudes toward it. Johns and Mills [2] reported that online mathematics tutoring can be as effective as face-to-face tutoring on students' mathematics achievement and positive self-concept, and attitudes toward mathematics learning. Mulenga and Marbán [6] examined prospective teachers' online learning mathematics activities in the age of the Covid-19 pandemic. Cluster analysis revealed that students engaged in the online learning of mathematics activities exhibited excellent online learning skills for mathematics in technology-rich environments. Ricker [8] utilised Hrastinski's theory of online learning as online participation and Moore's 3 types of interactions model of online student behaviour to determine whether 2 types of student LMS interactions could predict mathematics course performance. The study concluded that student clicks navigating the course content pages, and the number of times a student accessed resources, predicted student mathematics performance after allowing for the effects of student demographic covariates. Finally, according to a study [6], online learning in mathematics maximises personalised education of every student, and promotes sense of freedom during the Covid-19 isolation period. The study proposes a comprehensive and advanced pedagogic design to render lessons through virtual classrooms during and beyond the Covid-19 age.

While there are evidences in the literature about the advantages of online mathematics instruction, other studies have reported various challenges and barriers that users of technology encountered in the learning process [6]. In terms of challenges Agormedah, et al. [4] in a descriptive phenomenology study, found that poor internet connectivity and high cost of data were challenges faced by students. Owusu-Fordjour, et al. [9], said the high cost of internet data is one of the major challenges hindering students' online learning in Ghana. Tsitsia, et al. [10] revealed that students are also distracted mostly by home related factors. They recommended a blended teaching to manage cost and internet data usage, and prepare students in physical and virtual classrooms experiences.

In terms of barriers, Mailizar, et al. [11] categorised online learning barriers into student, teacher, curriculum and school levels. Student level barriers include skill and knowledge, motivation and e-learning infrastructure. Teacher level barriers comprise confidence, knowledge, belief and experience. Curriculum level barriers include structure of contents, assessment and e-learning resources that are aligned to the curriculum while at school level these consist of availability of software and hardware, internet, textbooks, school policy, time and technical support. These evidences suggest that the use of online learning platforms come with various challenges. Naidoo [12] found that most mathematics teachers are hesitant in using technology in their classroom, even though there are many digital applications and websites that can support learning and improve mathematics achievement. In the case of *vclass*, little is documented about users' experiences and challenges in learning mathematics, particularly in developing countries such as Ghana. This study seeks to fill the gap and to provide information about its sustainability. Due to the Covid-19 pandemic, Mulenga and Marbán [6] posited that "we are being challenged to think in different ways, to solve problems together, to collaborate and to communicate in different ways, to educate and be educated in a different way" (p. 3). In view of this, evidence from this study may serve as a lesson for the mathematics education community of learning regarding the prospects of deploying online learning management systems.

2.1 Conceptual Framework

The study focused on first time users' experiences of the LMS referred to as *vclass*. The users' experiences are conceptualised and framed as Strengths, Weakness, Opportunities and Threats (SWOT). These are constructs adopted from SWOT analysis conducted by Businessmen to identify viability of business setups. The strength of vclass refers to its ability to replace face-to-face instruction and facilitate effective online teaching, learning and assessment of mathematics. To support the use of the *vclass*, it is expedient to determine from the users' perspective if this strength was met, and to identify the weakness encountered by users in terms of challenges and barriers. As a new mode of instructional delivery, it would also be apposite to understand the opportunities that exist with deployment of *vclass* in teaching and learning mathematics as well as the threats resulting from refusal or complete abandonment of the system at student, lecturer or school levels.

3 Methodology

This qualitative study relies on the interpretive paradigm, and views experiences of people as ontologically internal and epistemologically subjective in nature. Therefore, the study views lecturers and students' *vclass* experiences as personal constructions which are subjectively and qualitatively interpreted. Collecting and analysing qualitative data provides better opportunity to understand practicality/usability issues as well as challenges of lecturers and students in the use of the *vclass*.

3.1 Participants

Participants for the study comprised ten students (3 in 4th year, 3 in 3rd year and 4 in 2nd year), and four of their lecturers. The students were pursuing the Bachelor of Mathematics Education programme, UEW. These students were contacted randomly, and they voluntarily shared their experiences in the use of the *vclass*. By the structure of UEW mathematics education courses, the students were exposed to ICT courses including Introduction to use of ICT tools, Basic programming techniques and Courseware design using multimedia tools. All of them disclosed they were intermediate users of ICT tools. Five of the participants reside on the university campus. The other five also reside outside campus, and did not have access to the university Wi-Fi network at their place of residence, except when on campus.

The four lecturers engaged the students in different courses using the *vclass*. One lecturer taught Ordinary differential equations and Partial differential equations. The other three lecturers taught Mechanics, Vector algebra and Methods of teaching senior high school mathematics respectively. Two were male lecturers who described their ICT proficiency as basic, while one male lecturer was at advanced proficiency level in ICT. The only female lecturer described her ICT proficiency level as intermediate. To assure the participants of their anonymity, only pseudonyms were used in this study.

3.2 Data Collection and Analysis

Data were collected through an open-ended item survey, and interviews. The open-ended item was constructed in Google forms to gather data on challenges encountered in using the *vclass*. Accompanying the Google forms was an informed consent message outlining the study purpose, the use of the data for publications, and participants' right not to respond to the item. Unstructured interview sessions were also conducted online with the ten students and four lecturers to share their experiences and challenges of *vclass* usage.

The interview data were transcribed and analysed by coding and categorising into themes and subthemes based on the SWOT constructs described earlier in this study. Open coding was first done to familiarise with the data, scrutinise and organise codes. This was followed by processing of codes, creating connections, and the grouping of excerpts of data into themes reflecting SWOT constructs in using the *vclass*. As recommended by Fusch and Ness [13], the principle of data saturation was applied to end further codes when it became obvious that responses produced were similar, or no new information or further coding were feasible. To ensure trustworthiness, clarity and accuracy of results, member checking was undertaken with participants. The data file on challenges in the use of *vclass* was download from Google forms. The file was then imported into INVIVO 12.0 software and run to obtain word cloud and reference codes of words that demonstrate the frequency of challenges encountered by students and lecturers.

4 Results

This section presents the experiences and challenges of the lecturers and students who used *vclass* as a teaching and learning platform. The interviews revealed that lecturers relied more on their personal computers, while smartphones were the main devices used by students in most of the interactions in the *vclass*. All the students interviewed admitted they mainly used the mobile phones, but occasionally used personal computers or tablets. This means that the students relied more on their own devices and data to access the *vclass* since they could not access the university Wi-Fi at home. When students rely on their own data to connect online, it is likely that they may not visit the *vclass* frequently for interactions, downloads or uploads of study materials [8].

4.1 Mathematics Lecturers' Experience in the Use of *Vclass*

The interview responses of the lecturers who shared their *vclass* experiences are presented in the following subthemes.

A. *Vclass* as a Course Creation Platform

The lecturers had different expressions regarding the user friendliness of the *vclass*. They said that the *vclass* was quite convenient, exciting and flexible to use in creating courses online in one's own time and space. The lecturers, however, pointed out that they had limited digital expertise to create courses on *vclass* but were able to learn new digital skills in content generation and course development, as articulated in the following excerpts:

Akos: the vclass has provided flexibility in terms of creating the course and course delivery. Of course you can be at the comfort of your home, create the course and upload online... Again, in term of course creation ..., it has helped to learn new technical skills ... learning how to create the course and upload them online.

Aliu: We don't have even the expertise of creating the course online. So we were experimenting, try and error kind of...

These responses support previous findings [11, 12] that first time course creators are often threatened by limited digital skills. However, they also tend to develop new digital pedagogies when they engage in developing courses online.

B. *Vclass* as a Platform for Delivery of Lectures

In *vclass*, all instructions are delivered to students online by text, audio and/or video with BigBlueButton. Expressing their experience of *vclass* lectures, the lecturers claimed the *vclass* was a suitable platform for virtual communication, collaboration and interaction with students, and for monitoring attendance. They admitted, however, that they had limited skills in presenting mathematics content on *vclass,* and felt it might be impossible to demonstrate mathematical concepts, show procedures and write mathematical symbols on the *vclass* as revealed in the following excerpts:

Akos: It has helped to improve virtual communication and collaboration ... I think the vclass has made me a more effective communicator. I will have to be more efficient in relaying information to the students. You have ample time to spend on the vclass interacting with the students.

Atua You'll be able to see those that are able to login ... like checking attendance ... [But] there is that inability to communicate effectively with the students online ... it is very difficult [with] video conferencing.

Aliu: I was teaching ordinary differential equations [with] symbols ... all these symbols were not found in Vclass.

These responses reveal the opportunities and threats which come with the deployment of emerging technology in teaching mathematics. Indeed, in the fourth industrial revolution led by technology [12], digital communication, collaboration, and interaction skills are undoubtedly key skills needed for active instructional delivery and workplace interactions. However, acquiring these skills depends on one's exposure or experience.

C. *Vclass* as E-assessment Platform

Regarding activities and resources for implementing e-assessment such as online quizzes, assignments and examinations, the lecturers shared their experiences in the interviews as follows.

Atua: when you give a quiz which is objectives you don't have to worry. The thing [vclass] will do the arrangement for you, mark for you, then you download the spreadsheet.
Akos: And another exciting thing is . . . how to create a question bank . . . it was exciting to do those things.
Adua: I downloaded all . . . the soft copies . . . marked as hard copies . . . I was having problem with the screen marking.
Aliu: . . . not sure if the actual student answered the assignment.

These responses illustrate the usefulness of the *vclass* in assisting lecturers to mark and store assessment results for future retrieval. Particularly, the development of a question bank was a new and exciting aspect expressed by the lecturers. There were, however, some frustrations as lecturers attempted to transfer the usual face-to-face assessment practices onto online assessment practices. While the frustrations might threaten the sustenance of *vclass*, research [2] suggests that they can also lead to new learning curve and opportunity for lecturers to devise novel ways to conduct valid and reliable e-assessment.

D. *Vclass* as an Innovative Way of Supplementary Face-to-face Teaching

The interview responses revealed that the lecturers valued the use of the *vclass* as innovation to the face-to-face interactions despite systems errors as highlighted below.

Akos: It is innovative way of teaching. . . . [that] should not be abandoned.
Adua: . . . I think . . . this vclass . . . we can upload things for students to get access to it first hand before . . . [But] it was impossible for 100 students to be enrolled.
Atua: [Vclass] is a record keeper like a database.
Aliu: The shared screen was a terrible one . . . [the] screen doesn't work.

The lecturers' responses suggest that *vclass* could serve as a database of students and lecturers' activities and interactions. The lecturers, however, lamented the video streaming errors with the BigBlueButton, system login errors and download/upload errors resulting from large enrolment, large videos, or mathematical symbols.

4.2 Mathematics Students' Experience in the Use of *Vclass*

Students' responses during the interviews are presented in subthemes as follows.

A. *Vclass* as Positive Intervention in the Era of Covid-19
All ten students expressed the view that it was the right intervention by the university to have introduced the *vclass* in the era of Covid-19 as exemplified here:

> *Sama: [I]t is something good . . . as we all know to help in terms of this crisis so that they can help finish our course outline on time.*
> *Ssala: it was big intervention management took . . . myself it helped me to put into practice my ICT.*

Students' comments reflect their feeling that the *vclass* can be a potential platform for addressing the mathematics learning crisis.

B. *Vclass* as a Platform for Uploading and Downloading Study Materials
The following excerpts show how three students responded to the issue of study materials.

> *Ssala: . . . some of the lecturers upload a video in a form of teaching and then you will listen.*
> *Sadu: they only put slides on the LMS, some courses you will only go and see slides on the LMS, no explanation.*
> *Saku: Is not that interactive . . . sometimes they only put slides on the LMS . . . and that doesn't help.*

These comments reveal that students view the vclass as a platform where lecturers produce mathematical content in the form of video, audio and text and upload it for them to download and learn at their own pace and time. It also reveals that the materials presented to students were not quite interactive for self-study, and did not meet their learning needs.

C. *Vclass* as a Favourable and Useful Instructional Platform
In terms of instructional delivery, students responded that the *vclass* was useful as illustrated in the following excerpts:

Sadu: It helps in finishing the course outline on time . . . the number of weeks in a semester and the workload meeting face-to-face for 2 hours every week would not help. So the LMS has come to help . . . so much in exploring much in internet.

Satia . . . lecturers upload a video in . . . you will listen and . . . involve almost all your senses like your ears, your eyes, everything is very attentive just like how you do it in the lecture room . . . you are relaxed.

Ssala: the LMS was able to make lessons to go fast. We are able to complete most of the topics compared to the face to face.

These comments illustrate that students view the *vclass* as comparable to face-to-face teaching and as an opportunity to explore the internet anytime and anywhere. Thus, through the *vclass*, students gained skills by taking the courses and conducted research online to develop their own learning.

D. *Vclass* as an E-assessment Platform

In terms of assessment, students expressed views that reflect both the opportunities and weaknesses of using *vclass* for e-assessment, as exemplified in the following two excerpts.

Sama: . . . the assignment and exams were marked by the LMS, especially the multiple-choice.

Ssule: we were not getting much feedback from the lecturers anyway, so if the LMS will also be improved in such a way that there can be some prompt feedback from the lecturers.

Students' responses suggest that even though the *vclass* supports e-assessment and eases the workload of lecturers, they did not receive prompt feedback from their lecturers.

4.3 Challenges Experienced by Lecturers and Students in Using *Vclass*

Word Cloud using INVIVO 12.0 software was used to categorise the data according to the most occurring challenges in terms of system functioning, course creation, lesson delivery, and assessment and support services experienced by both lecturers and students. The results are presented in Figs. 2 and 3.

Fig. 2. Lecturers' most frequent challenges in vclass

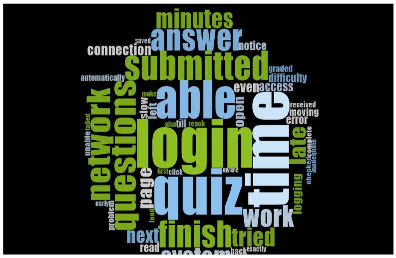

Fig. 3. Students' most frequent challenges in vclass

Figure 2 shows that the most frequent or pronounced challenge encountered by lecturers was *time* i.e. *time* to create course and questions bank, *time* for students to answer questions, and *time* to give marks online. This was followed by *questions* to set, and *login* to do quizzes and submit online. Issues concerning system network, answers and mathematics symbols were other frequently occurring challenges faced by lecturers in the use of the *vclass* (Fig. 2). Also, Fig. 3 shows that the most frequent or pronounced challenge encountered by students was *login*, followed by *time* and *quiz* submission on vclass. These issues were mentioned 42, 42 and 40 times by the students. These challenges demonstrate the level of students' frustrations and anxieties in the use of *vclass*.

5 Conclusion

The study shows that *vclass* experiences of lecturers and students can be summarised into strengths, weaknesses, opportunities and threats. The strengths were internal positive attributes of *vclass* that allowed users to operate efficiently to achieve their learning goals. The study found that the *vclass* platform was easy to create courses, deliver live video lessons using BigBlueButton, create question bank and e-assessment including system marking, quiz, assignment, chat, forums, etc. The weaknesses included aspects that affected lecturers' and students' effective use of the *vclass* platform. In this study, these were lack of quick feedback, low digital literacy levels, lack of mathematical symbols, and inability to conduct practical lessons. The opportunities were experiences that could be leveraged to gain advantage in the use of the *vclass* in learning mathematics. These included improvement in the digital skillset of students, and the digital pedagogy of lecturers, transformation of e-assessment skills of lecturers, promotion of the reuse of existing courses, use of assessment data in research/decision making, and the adoption of a hybrid mode of mathematics instructions. The threats were activities that negatively impacted on the effective use of the *vclass*. In this study, these comprised assessment security, registration challenges, and login and network problems.

Based on the experiences shared by lecturers and students, the study concludes that there are more strengths and opportunities than weakness and threats when *vclass* is used for mathematics instructional delivery. Hence, the *vclass* should be encouraged and sustained.

6 Recommendations

The study recommends that the UEW should improve the bandwidth and connectivity, and include a Maths built-in app to facilitate effective online interaction among mathematics lecturers and their students. There is also the need for the university to organise training and professional development sessions for lecturers on the principles and theories of instructional design, course creation, digital pedagogy and e-assessment. Lecturers should be trained on how to use data in the *vclass* for research, SWOT analysis and decision-making regarding performance, assessment and online interactions. Students should also be provided with regular orientation and support services at departmental levels, to enable them to adjust to the new learning platform. Finally, the study recommends a hybrid mode of mathematics teaching and learning to enable both lecturers and students to make amends for the weaknesses and threats associated with the *vclass*.

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Needs and Challenges of Smart Agriculture and Entrepreneurship Education – A Case Study by the University of Agricultural Sciences, Dharwad, Karnataka, India

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Abstract. India has a history of more than 100 years of organised teaching, research and development of agriculture, and has grown from few teaching and research institutes at the beginning of 20th century to one of the most productive, vibrant and advanced agricultural systems in the world. Agriculture plays a vital role in the Indian economy and contributes 17.4% to the country's GDP. Government of India has launched several programmes for sustainable development and the state of Karnataka now aspires to be the national hub for smart agriculture. The University of Agricultural Sciences, Dharwad (UASD) has been exploring the possibility of establishing the Centre of Excellence in smart agriculture with the objective of skilling, re-skilling and up-skilling agriculture graduates, and to provide industry-ready man power and to educate farmers through the use of ICT. The university has been a pioneer in imparting quality agriculture education, and has introduced digital technology in several domains. A thrust has been given to areas such as agri-informatics in precision agriculture, conservation agriculture, mechanisation, use of robotics, drone technology, artificial intelligence, machine learning, cloud computing, trade and market intelligence, weather forecast and developing suitable agri-web-portals. The role of agri-business and agricultural entrepreneurship is critical in the overall economy of many developing countries. UASD is implementing a World Bank funded Institution Development Plan (IDP) under National Agriculture Higher Education Project (NAHEP) which has a prime objective of developing entrepreneurship and promoting start-ups. The UASD is utilising digital technology in order to empower students, staff and farmers in future digital agriculture and allied sectors.

Keywords: Smart agriculture · Entrepreneurship · Start-up · Higher education · Digital transformation

1 Introduction

India has a history of more than 100 years of organised teaching, research and development of agriculture and has grown from few teaching and research institutes at the beginning of 20th century to one of the most productive, vibrant and advanced agricultural systems in the world. Starting with only 17 Agricultural, three Veterinary

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and one Agri. Engineering colleges in 1950, now the country has 63 State Agricultural Universities (SAU), four Deemed Universities (DU), three Central Agricultural Universities (CAU) and four Central Universities with more than 400 constituent colleges, and intake capacity has risen from less than 5,000 to more than 50,000. The Indian Council of Agricultural Research (ICAR) - SAU Model has been quite successful and adopted in many Asian and African countries. The Government has made substantial investment for development of research capacity within the ICAR and SAUs. ICAR has provided leadership, resources and environment for development of a pluralistic system, and also facilitated partnership with international organisations which paid rich dividends in terms of making the country self-sufficient in food production, diversifying production and reducing rural poverty.

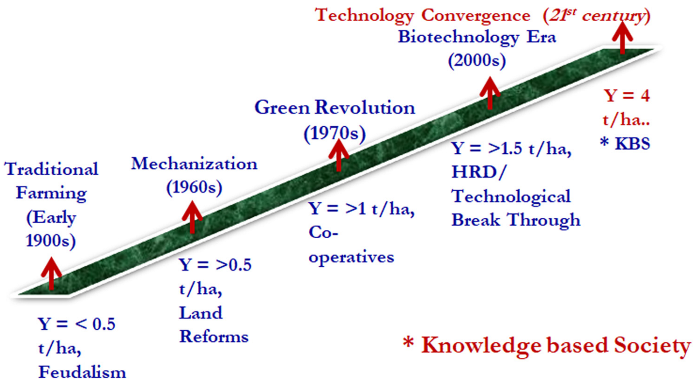

Fig. 1. Distinct transitions: history of agriculture.

India has achieved a significant improvement in the productivity of food grains from the level of 0.5 t/ha in 1900 to 4 tones/ha in 2021.This was made possible due to several interventions such as mechanisation in the 1960s, followed by a green revolution (1970s) and biotechnology in 2000 (Fig. 1). The Indian Council of Agricultural Research (ICAR) - SAU Model has been quite successful, and was adopted in many Asian and African countries. The Government has made substantial investment for development of research capacity within the ICAR and SAUs. ICAR has provided leadership, resources and environment for the development of a pluralistic system, and also facilitated partnership with international organisations which paid rich dividends in terms of making the country self-sufficient in food production, diversifying production and reducing rural poverty.

ICAR is the nodal agency for Research and Development and the Agriculture Minister of Government of India is the President. The Director General and Secretary DARE (Directorate of Agricultural Research and Education is the executive head. It has seven divisions, namely natural resource management, crop science, horticulture science, animal science, fisheries science, agriculture education, agricultural engineering and agricultural extension. It has research centers on different crops located in different agro climatic zones of India.

National Agriculture Research Education System (NARS) is one of the largest in the World. In addition to universities and colleges, it has 101 ICAR institutes, 79 All India coordinated research projects (AICRP) and 721 Krishi Vignan Kendras (Farm Science centers) (Fig. 2). The widely spread and specific NARS system established strong linkage with research, extension and the education systems in India. AICRP and KVK are part of State Agriculture Universities, ICAR closely linked with all State Agricultural Universities (SAU).

Fig. 2. National agriculture research education system.

Several new initiatives have been introduced in the education system in India that includes, implementation of fifth Deans Committee Recommendations with a focus on Experiential Learning and student READY (Rural Entrepreneurship Awareness and Development Yojana) programmes, apart from including several new courses in emerging areas of Science and Technology. This has brought a major qualitative and quantitative impact in the teaching and learning process.

Some consider entrepreneurship as a very specific occupation, related to Schumpeter's creative as a key driver of economic growth and job creation [2]. This is also the most common reason [3] why researchers and experts promote entrepreneurship education. Lingelbach [4] suggested that, "Yet, entrepreneurship in developing countries is arguably the least studied significant economic and social phenomenon in the world today."

Higher education in India is well established, and caters to the needs of a growing population. Some of the facts about higher education in India include, 993 Universities, and under these universities there are 39,931 colleges affiliated to them. In addition, there are 10,725 standalone institutions. Total enrolment of students in higher education is 37.4 million (19.2 million male & 18.2 million female), out of which 79.8% study in undergraduate degree programmes (maximum in B.A., B.Sc., B.Com.). There are only 0.5% (1,69,710) in doctoral programmes (PhD) mostly in science, followed by engineering and technology.

2 Key Challenges and Policies for Higher Agricultural Education

There are needs to balance elements in the higher agricultural education, that includes balancing tradition and change, building universities as innovation hubs, improving leadership in universities – learning lessons of strategic management from the best in business, and the role of online learning in reforming India's education system.

The present strategy is to align the agricultural education system in tune with the National Education Policy (NEP) – 2020 of Govt. of India [1]. The national education policy 2020 is distinct and broad-based and gives choices to the students to pursue their interest, and to excel in the area of their interest apart from giving a thrust to skill acquisition. The NEP 2020 vision is to enhance the Gross Enrolment Ratio (GER) of higher education to reach at least 50% by 2035. The present GER is 26.8% as compared to USA (86.7%), Germany (65.5%), and China (39.4%).

NEP 2020 includes many features listed below:

1) It emphasises large, multidisciplinary universities and colleges.
2) Liberal and flexible undergraduate programmes.
3) Faculty and institutional autonomy.
4) National Research Foundation.
5) Better regulatory system.
6) Expansion and improvement of new architecture, research universities, teaching.
7) Universities and colleges; degree by granting powers to them.
8) Overall changes from school level to faculty upgradation.

Several policy initiatives are taken in enhancing industry-academia linkage, Alumni network, dual degree programmes, and specialised courses for entrepreneurship, skill and personality development. The visibility of Indian universities is enhanced through attracting international students mainly from African and Asian countries. To enhance faculty competence, both ICAR and State Governments are encouraging training programmes both at national and international level in cutting-edge technologies. UASD is in the forefront in establishing entrepreneurial and start up eco systems. Important ones are listed below:

1) Encouraging startup culture through funding from RKVY-RAFTAAR of the Government of India, ICAR-NAHEP of the World Bank.
2) Biotechnology Industry Research Assistance Council (BIRAC) of the Department of Biotechnology, the Government of India.
3) Karnataka Innovation and Technology Society (KITS) from the Government of Karnataka.

With the implementation of new policies, there is likely to be enhancement in Gross Enrollment Ratio (GER) in higher education, which eventually may lead to India becoming a USD 5 trillion economy by 2025. apart from sustaining Gross Domestic Product (GDP) growth rate.

The development and usage of a Smart Agriculture system based on artificial intelligence and machine learning is changing the agriculture sector by not only improving the crop production, but also making it cost effective. Recognising the importance of artificial intelligence (AI), the National Institution for Transforming India (NITI) Aayog initiated a National Programme on AI, with a view to guiding research and development in new and emerging technologies. Considering the growing acceptance of farmers for the internet and mobile based services, the Indian Council of Agriculture Research (ICAR) made an attempt to provide valuable agro-met information to the users through web portal (Crop Weather Outlook) which provides 'Value Added Agro-advisory Reports'. University of Agricultural Sciences (UAS) Dharwad has excelled in the area of smart agriculture and entrepreneurship development. The University stands in the 9th rank at national level and first in the state.

3 Agriculture Education and Careers

The role of agricultural education is to provide improved, relevant and effective teaching [5]. Nawaz, [6] referred to the lack of business education in agriculture, and Knudson [7] confirmed that agricultural entrepreneurship is at an early stage of development. Inadequate education and training as well as technological know-how make small businesses less competitive and more vulnerable to the economic downturn [8]. Agricultural education as under-graduation and post-graduation is available to the students in State Agricultural Universities (SAU) as well as Central Universities (CU). The students seeking admission for under-graduation programmes must have studied two years of pre-university course (PUC). There are total of 71 Agricultural Universities in India spread in different states. The respective state conducts a Combined Entrance Test (CET) for the students, and selects the students based on the merit of both their regular exam and the marks obtained in the CET. Universities follow guidelines of the state government with respect to the quota/reservation of seats for different categories such as a Scheduled Caste (SC), Scheduled Tribes (ST) and otherclasses. The Undergraduate course of BSc. Agriculture, Horticulture, Sericulture etc., are for the period of four years. During the last decade, the competition for admission to agricultural courses has increased due to more job opportunities in government and private sectors.

Students join the course with different aspirations and aspire for a job such as an appointment in government organisations, universities, and jobs in banks.

Table 1. Placements of graduates of UAS Dharwad, during 2008 to 2018.

Sl. No	Career working field	Number	Percentage
1	Government jobs	300	37
2	Private	393	49
3	Bank	33	4
4	Entrepreneurs	60	8
5	Farming	20	2

The analysis of the data of the passed-out students from 2008 to 2018 reveal that, 49% of the students secured job in private sector followed by government jobs (37%), banks (4%). Only 8% choose to become entrepreneurs, and 2% opted for farming (Table 1 and Fig. 3).

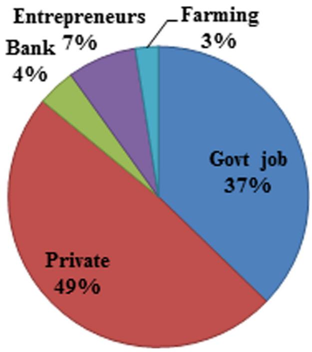

Fig. 3. Placements of graduates of UAS Dharwad during last 10 years.

It clearly indicates that students are more oriented towards the Government or a private job, rather than starting their own enterprise.

4 Smart Agriculture Initiatives at UAS Dharwad

Agriculture plays a vital role in the Indian economy and contributes 17.4% to the country's GDP. The Government of India has launched several programmes for sustainable development and state of Karnataka now aspires to be the national hub for smart agriculture. The University of Agricultural Sciences, Dharwad, has been exploring the possibility of establishing the Centre of Excellence in smart agriculture, with the objectives of skilling, re-skilling and up-skilling agriculture graduates, thus providing industry with ready manpower, to educate farmers through the use of ICT. The university has been a pioneer in imparting quality agriculture education, and has introduced digital technology in several domains. The thrust has been given to agri-informatics in precision agriculture, conservation agriculture, mechanisation, use of robotics, drone technology, artificial intelligence, machine learning, cloud computing, trade and market intelligence, weather forecasting. And developing suitable agri-web-portals. Efforts have been made in implementing an Academic Management System (AMS), a Human Resource Management System (HRMS), a Public Finance Management System (PFMS), and other web portals in daily activities of the university. Farmers are educated through university-owned FM radio, sending updated information on weather, outbreak of pest and diseases, and timely management practices through mobile apps and SMS.

In view of the COVID-19 pandemic during 2020, on line classes and on-line examinations have become regular phenomena. To facilitate the students in better learning, all the course contents are digitised and uploaded on the university website. The proposed Centre of Excellence in Smart Agriculture will have training modules for agriculture informatics, simulations, agriculture equipment design and modifications, machine learning and imaging. It is also proposed to create the digital assets, develop Virtual Learning (VR) ready contents, and develop 3-D contents on advanced/smart agri-technologies. Which will provide a wonderful learning experience not only for the students, but also for the farmers.

An agri-war-room called Raith Chetan (farmers' helpline) has been established to help the farmers not only by educating them, on-line, on cultivation practices but also on marketing of the produce like the e-National Agriculture Market (e-NAM) by which several thousand farmers have benefited during the lockdown period. GIS technology has been profusely utilised in soil resource mapping, nutrient mapping, land suitability evaluation for different crops, crop coverage, identifying water-logged and saline areas, watershed characterisation and planning, land and land capability classification. UAS, Dharwad has taken initiatives in the setting up of a GIS lab and remote sensing facilities through which early warnings and forecasting of weather, pest and disease incidence and crop coverage are being monitored.

Facilities are also created for an Automatic Smart Irrigation Decision Support System (SIDSS) to educate the farmers in effective water management. Watershed delineation, mapping soil resources, land capability and crop suitability, identification of water logged and saline prone areas, flood-mapping, land use and land cover, nutrient mapping for precision agriculture are being done at UAS, Dharwad. Algorithms are being developed for disease-forecasting, nutrient management, precision water management and sensor-based irrigation scheduling in association with Indian Institute of Technology (IIT), Dharwad and Fourth Paradigm Institute, Bengaluru.

Farmers are being trained to use the National Agriculture Market (e-NAM), an online trading platform for agricultural commodities set up by the Government of India. The market linkage is a must for agriculture, and to realise these, models on price forecasting for different commodities are developed by the University. Efforts are being made to develop drones for the spraying of chemicals and also to monitor crop health status. Efforts are also being made in establishing a Centre of Excellence in Smart Agriculture with a view to skill, reskill and upskill agriculture graduates, providing industry-ready manpower and information to educate farmers in smart agricultural technologies at UAS, Dharwad.

5 Entrepreneurship Development Initiatives at UAS Dharwad

5.1 Course on Entrepreneurship Development in Undergraduate (UG)

The fifth Dean's Committee of Indian Council of Agricultural Research (ICAR) has introduced entrepreneurship development related courses as a mandatory course with two credits in all degree programmes. This was one of the important changes brought by the orientation of the education system with the introduction of exclusive courses in Entrepreneurship development, with 2 credit hours for undergraduate students.

The course curriculum includes topics, for example the concept of entrepreneurship, project identification, management, supporting institutions and Government schemes. Students visit different institutes, and entrepreneurship is a part of their practical classes. During the final year, Student READY (Rural Entrepreneurship Awareness and Development Yojana) is offered, which includes placement of students at the grass-roots level unit of the Agriculture Department called by name Raita Samparka Kendra (farmers' contact centre) for eight weeks, to understand the agricultural ecosystem in rural areas and the practices adopted by the farmers.

After eight weeks, they would undergo two weeks of internship in the Agri-Clinic, where they conduct diagnosis of soil/plants followed by five weeks of institutional attachment and two weeks of Industrial attachment. The institutional attachment includes placement in Krishi Vignana Kendra (KVK), Agricultural Research Stations (ARS), horticulture or seed farm and processing plants.

Thus, the programme of 20 credit hours provides an opportunity to learn in the field, and develop feasible enterprises, and the programme is called student READY. During the second semester, students undergo experiential learning modules in five different subject-matter areas (Fig. 4).

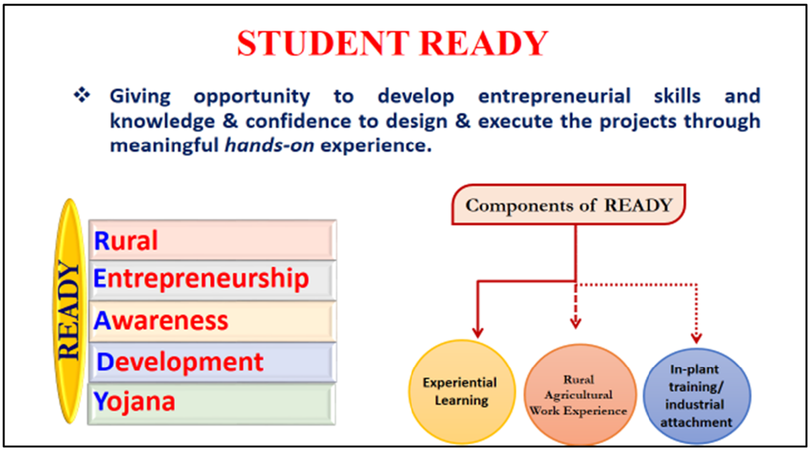

Fig. 4. Curriculum transition with the thrust on hands-on experience and entrepreneurship.

5.2 EDP and Ideation (Ideathon) Workshops

The role of agri-business and agricultural entrepreneurship is critical in the overall economy of many developing countries. Agri-business represents perhaps half of the Gross Domestic Product (GDP) in many countries and over 2.5 billion people in these countries depend on agriculture for their survival [9].

UASD is implementing the World Bank funded Institution Development Plan (IDP) under National Agriculture Higher Education Project (NAHEP) which has a prime objective of developing entrepreneurship and promoting start-ups. Under the

Table 2. EDP conducted under NAHEP-IDP during 2020–21.

Particulars	Training or workshop	Percentage
Total programmes	6	-
Total participants	1,688	-
SC and ST participants	292	17
SC and ST girls	122	7
General girls	644	38

project, six EDP programmes covering 1688 students have been conducted during 2019–21.

It was observed that the participation of girls was on a par with boys, and care was taken to ensure participation of special category students namely schedule caste and schedule tribes (Table 2 and Fig. 5). In addition, sixteen webinars on opportunities in entrepreneurship development was conducted and benefitted 2,593 students.

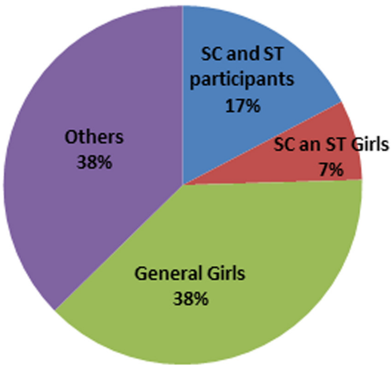

Fig. 5. Representation of different category participants in Ideathon workshop.

Another project called RAFTAAR (Remunerative Approaches for Agriculture and Allied Sector Rejuvenation) promotes Agribusiness incubator. It has promoted over 20 startups in agriculture and allied areas. A Section 8 Company, ASTRA (Association for Startup and Technology Refinement in Agriculture) has been established to support entrepreneurship and start-ups by students. Efforts are being made to establish close linkage with industries, as well as alumni entrepreneurs, to strengthen the endeavor of entrepreneurship development in agriculture.

5.3 Incubation Centre

Under the flagship programme of Karnataka Innovation and Technology Society (KITS), Department of Information Technology (IT), Biotechnology (BT) and Science and Technology (ST), Government of Karnataka, the incubation centre with common instrumentation facility was established at the University of Agricultural Sciences, Dharwad for promoting the innovation in agriculture and biotechnology, with a grant of 60 million rupees (approximately 716,000 Euro). Since the inception of the project, several workshops/conferences were organised to develop skill enhancement.

The state government's novel initiative, New Agriculture Incubation Network (NAIN), was established under the Karnataka Start-up Policy for 2015–20 by the Department of Information Technology, Bio-Technology, Science and Technology to encourage students, research scholars and alumni to share their ideas, to solve chosen local problems, and to validate, refine and nurture ideas, provide an ecosystem to convert ideas into proofs of concept, and convert them into minimum viable products/services, and encourage and lead the teams towards setting up a business enterprise.

6 Conclusion

The University of Agricultural Sciences, Dharwad has been exploring the possibility of establishing the Centre of Excellence in smart agriculture with the objectives of skilling, re-skilling and up-skilling agriculture graduates, thus providing industry-ready manpower, educating farmers through the use of ICT. The UAS Dharwad has been a pioneer in imparting quality agriculture education, and has introduced digital technology in several domains in order to digitally empower students, staff and farmers for digitally-enabled future agriculture, and allied sectors.

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Learning with Digital Technologies

Vocational Education During School Shutdown - A Danish Case on Emergency Remote Teaching

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Abstract. This paper focuses on the emergency remote teaching during the temporary shutdown of physical learning environments in the spring of 2020. It presents findings from a survey among about 14,000 Danish teachers and students at vocational colleges and upper secondary schools regarding their experiences with online education. The analysis and interpretations of the survey data provide evidence suggesting that the teachers generally need professional development regarding online education and blended learning events. Most often, they did not succeed in their attempts to realise the potentials of online education: First, they did not manage to coordinate their expectations regarding the students' daily workload and meet their individual need for teacher support. Second, they did not provide clear announcements and formative feedback. Third, they had difficulty supporting students experiencing learning difficulties and they did not support students with motivational challenges due to social isolation.

To overcome these challenges, teachers need to be more informed by data and research than they were during the emergency remote teaching. This includes information derived from analysis of local data on students' independent and collaborative work, learning challenges, and perceived self-efficacy. Moreover, it includes information about the main findings in research about the benefits of blended learning compared to online teaching and f2f teaching.

Keywords: Blended learning · Online education · Vocational education · Emergency remote teaching · Case study

1 Introduction

The Danish vocational colleges and upper-secondary schools, like many schools around the world, had to introduce emergency remote teaching in the spring of 2020. Faced with the risk of spreading COVID-19 virus, the purpose was to maintain ongoing education during the school shutdown. The teachers at all the schools made an extraordinary effort to reorganise teaching and learning activities. The paper analyses the main experiences of the teachers and students in the spring of 2020.

Teachers usually obtain knowledge about teaching methods by reflecting on their experiences in previous teaching situations. Their individual reflections often begin

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while the teaching is in progress and continue afterwards [1]. These reflections regarding previous teaching and learning events may increase their ability to choose effective teaching methods. However, these reflections relate to previous experiences, so they are less useful when teachers need to carry out their work in completely new ways. Faced with an immediate need to reorganise educational events, most teachers lacked experience of and routines for carrying out online education.

Over recent years, all vocational colleges and upper-secondary schools implemented 1:1 environments where each student has a laptop or tablet with internet access and all students are digitally literate. The Danish schools were among the first in the world to implement such 1:1 learning environments [2]. For years, the level of digital literacy among students in Denmark has been among the highest in the world [3]. Moreover, the need of Danish teachers for professional development regarding ICT skills for teaching has been among the lowest in the world. Before the shutdown of classrooms, just 8% of upper-secondary teachers reported a high level of need for professional development in this area [4, Table 1.5.23]. However, they had no experience with emergency remote teaching and it was a challenge for them to adjust to it.

Accordingly, the paper addresses these two research questions:

1. What were the main challenges regarding emergency remote teaching at vocational colleges and upper-secondary schools in the spring of 2020, and
2. How can teachers overcome these challenges in future?

The paper addresses these questions by analysing data from a survey conducted shortly after the closure of the physical learning environments in the spring of 2020. The respondents included about 14,000 Danish teachers and students. Based on an analysis of data about their challenges and experiences, the paper examines how the teachers organised their online teaching by adopting a trial-and-error strategy.

Furthermore, it explores an alternative approach in which the teachers adopt a research-informed strategy. In particular, it explores how teachers can handle future disruptive events if they are informed by research findings on technology-enhanced teaching and learning activities.

2 Theoretical Framework

The theoretical framework includes theory on basic forms of teaching. This notion refers to constructions suitable for analysing and understanding different types of teaching [5]. The paper explores two basic forms of teaching in digital learning environments: 1) teacher-centered and 2) student-centered teaching respectively. There is research evidence suggesting that a synthesis of these forms of teaching generally has a greater impact on student learning outcomes than traditional f2f education [6].

Essentially, the former involves communication between a teacher and students (oral teaching, guidance, written dialogue and oral and written feedback). In general, such teacher-centered activities influence students' learning outcomes positively [7]. When teachers and students are not allowed to meet in a classroom, teachers can either organise one-way communication via the school's digital learning platform or apply a more dialogical approach and communicate with individual students or groups of students via online media.

The second basic form of teaching and learning is defined as “teaching with a high degree of individual work or group work” [5]. When teachers organise such activities, they make a number of choices regarding for instance small-group interaction and learning content and tasks. The students work individually, in pairs or in groups, and they can adjust the time they spend on each task according to their prior knowledge and current abilities.

The teachers need to evaluate these activities with virtual attendance. In particular, the teachers need to evaluate the student-centered learning processes systematically in relation to academic and other expectations, which can be defined in terms of the students’ zone of proximal development [8]. Whenever expectations fall outside this zone, students risk being demotivated by tasks that are too difficult, or, conversely, do not learn anything at all because the tasks are too easy for them. In consequence, the teachers have to:

- Identify the students’ zone of proximal development
- Select appropriate student tasks
- Provide feedback on the students’ work in progress
- Evaluate their final results

Sometimes, teachers use a retrospective and summative approach to determine the students’ current knowledge and skills or to grade student work. This approach is less suitable than a formative approach when it comes to determining the students’ developmental potentials. Additionally, the students’ belief in their own ability may suffer when their assignments and other products are returned with comments regarding their flaws and shortcomings.

There is also research evidence suggesting that summative evaluations in the longer term demotivate many students [9]. Although they may learn from their shortcomings and mistakes in the short term, the use of summative evaluation may decrease their motivation and momentum in the end.

Frequently used complementary approaches include formative feedback and process-oriented evaluation. About twenty years ago, researchers provided evidence suggesting that formative feedback has a relatively large influence on students’ motivation and learning outcomes [10]. I addition, there is research evidence suggesting that formative evaluation fosters these factors a great deal [7]. When reflecting on their formative feedback, the students are encouraged to complete and present the results of their self-directed activities. In general, the benefits of such approaches are twofold: strengthening the teachers’ insight into the students’ learning processes, and fostering these processes.

In general, the teachers use various approaches to provide feedback on the students’ work, but there has been a shift in focus from result-oriented to process-oriented evaluation in the Danish educational system. More and more frequently, teachers provide feedback on work in progress tailored to the students’ educational needs and challenges and applied to strengthen their continued learning processes.

3 Methodology

As mentioned above, the paper analyses data from a survey among teachers and students at vocational colleges and upper-secondary schools. This survey was conducted in close collaboration between a Danish knowledge center and a Danish think-tank [11]. The author of this paper provided research guidance.

The survey was conducted in 2020 from April 27 to May 8 at schools offering upper-secondary education after the compulsory ten years of education at primary and lower-secondary schools. The total number of schools was 55. The forms of upper-secondary education involved are shown in Table 1.

Table 1. Overview of schools and forms of education involved in the survey (some schools offer more than one form of education)

Form of education	Explanation	Number of schools
VET	Vocational Training	25
EUX	Vocational Student Exam	22
HF	Higher Preparatory Exam	20
STX	General Student Exam	25
HHX	Mercantile Student Exam	9
HTX	Technical Student Exam	8

1,886 teachers and 12,352 students responded to the survey. The main theme in the teachers' questionnaire is their work experiences. The questionnaire focuses on the teachers' experiences when organising teaching and learning activities in which physical attendance was not possible. They were asked to relate to statements about their work experiences with online teaching in the last two full teaching weeks in April 2020. The main theme of the students' questionnaire was their experiences of online teacher-centered and student-centered activities during the same weeks.

4 Results

In the spring of 2020, the majority of teachers obtained insight into online teaching, which they expect to make use of in the future to develop and improve online teaching [11]. In particular, teachers who already had some experience in this area obtained insight that they plan to use in the future.

The transition to pure online teaching due to the closure of the physical learning environments was a top-down decision. When this decision was announced, there were no clear guidelines for the necessary reorganisation of teaching at the vocational schools and colleges [11]. Although some school leaders inspired the teachers and provided feedback on their online teaching, a number of teachers were given inadequate guidelines:

- One in every eight teachers "received useful and sufficient guidelines for distance learning from the school" either very little or not at all.
- One in every four teachers "received useful and sufficient support and guidance from the school in relation to the choice and use of digital technologies" either very little or not at all.
- One in every four teachers said that their school "organised sharing of knowledge about and experience with distance learning between colleagues" either very little or not at all.
- About half of the teachers said that their school "organised sharing of materials and/or teaching courses between colleagues" either very little or not at all.

In this situation, the teachers increased their knowledge sharing about: 1) the use of digital technology and materials, and 2) the reorganisation of teacher-centered and student-centered learning events.

Teachers primarily shared knowledge about and reorganised their oral communication using interactive video methods. In general, the influence of interactive video methods is above the average for all the methods used (Table 2).

Table 2. The effect of using digital technology [12]

Type of method	Influence (effect size)
Interactive video methods	0.54
Average of all types of methods	0.40
Programmed instruction	0.23
Web-based learning activities	0.18

The teachers often scheduled lessons on the screen for an audience of students lying in their beds with their cameras and microphones turned off. The teachers could easily be seen and heard, but it was obviously much more difficult to ensure that the students were paying attention. Some students were distracted by, for example, social media updates [11].

When they perceive academic instruction and web-based learning as homework, their industriousness and self-discipline varies as with other types of homework. Consequently, not all students managed to prepare for scheduled lessons by watching video-based homework.

The influence of interactive video methods on student learning may also decrease if the students regard them as elements of programmed instruction or web-based learning activities. This is in line with general research findings. As indicated in Table 2, programmed or web-based instructional activities have relatively little influence on students' learning outcomes.

Although the online teaching was never referred to as 'programmed instruction', it did resemble programmed instruction to some extent. For example, this form of instruction is often monotonous because it involves sequences of repeated activities such as introduction of new material, assignments, tests, repetitions and additional tests. In the spring of 2020, the teachers and students experienced increased uniformity: “Both teachers and students felt that the teaching became more monotonous in the way it was approached during the COVID-19 virus shutdown” [13, p. 7].

Due to inadequate coordination between the teachers, they provided plenty of assignments: “The first period of teaching was characterised by the students being given tasks that they had to perform individually or in groups and hand in for assessment. In other words, the teachers provided plenty of tasks to ensure that the students had enough to do during the allocated teaching time” [13, p. 5]. The increased amount of homework affected the students’ motivation and learning outcomes negatively. Students were generally less motivated and learned less [13, p. 5].

Moreover, many students called for clear announcements regarding their self-directed learning activities. The teachers generally: “Had difficulty expressing their expectations to the students. Teachers are used to expressing and explaining their expectations during face-to-face contact with students. When this possibility disappears, it is much more difficult to ensure that individual students understand the presentation” [13, p. 6].

In addition, many students wanted formative feedback and guidance when working independently or in pairs or small groups. As previously mentioned, the students may learn a lot from this kind of feedback. Ideally, they can resubmit some of their work to obtain summative feedback. However, most students wanted feedback that was more comprehensive in the spring of 2020.

Regarding the amount of feedback, the teachers were more positive than the students were [11]. However, the teachers provided so many tasks that they did not have “the opportunity to give feedback on all the tasks” [13, p. 6].

In the regular classrooms, most teachers continually consider the students’ need for support related to individual tasks and collaborative work. After the school shutdown, they were not able to develop alternative methods to cater for this need. Therefore, it was more difficult to assess students’ motivation, working efforts and learning outcomes during the school shutdown [11, p. 5].

During face-to-face teaching, the teachers circulate among student groups, answer questions and provide ongoing feedback to the students regarding their self-directed activities. When this is no longer possible, the teachers tend to decrease their observations. In consequence, they knew less than usual about the students’ motivation and the extent to which the students actually met the given learning objectives. Many teachers failed to support their students adequately during the shutdown of the classrooms in the spring of 2020.

In other words, the teachers did not have time to develop alternative methods to observe and support the individual students. Consequently, the students found it harder to work with the educational materials. This included students who felt they were academically weak. It is significant that students at the lower end of the achievement scale felt a lack of support from their teachers more than students at the other end of the same scale did [11].

5 Discussion

In general, feedback for teachers provided by an external research-informed certifier improves technology-enhanced education and e-learning [14]. In particular, it promotes consistency between expected learning outcomes, preconditions as regards content, duration, flexibility, use of digital platform etc., and design in terms of the organisation and evaluation of learning activities. Therefore, the vocational colleges and upper-secondary schools might consider implementing a system of certification of e-learning concepts in future.

Furthermore, the teachers could apply more research-informed practice. This does not mean that they regard research findings as a recipe for action, but research does provide useful information whenever they plan educational events in 1:1 learning environments. For example, there is research evidence suggesting that clear announcements influence students' learning outcomes to a considerable extent. In the first weeks after the sudden shutdown of the classrooms, it is quite understandable that not all announcements and learning objectives were completely clear. Afterwards, however, there was a need for clearer announcements and objectives to ensure that control of the learning activities was not transferred in its entirety to the students.

In general, students' control over learning has low influence on their performance compared to actions like formative evaluation and feedback, and clear announcements and learning objectives (Table 3).

Table 3. Selected effect sizes [12]

Type of method	Influence (effect size)
Students' perceived self-efficacy	0.92
Formative evaluation	0.90
Formative feedback	0.75
Clear announcements	0.75
Clear learning objectives	0.50
Average of all types of methods	0.40
Students' control over learning	0.04

Usually, students' learning processes are assisted whenever they receive formative feedback and have sufficient time to learn from this feedback and possibly resubmit some of their work (Table 4). This includes feedback on activities requiring them to work alone or in groups, but as mentioned above, many students experienced little motivating feedback from their teachers in the spring of 2020.

The students' motivation relates to their perceived self-efficacy, which correlates with their learning outcomes [15]. When they feel that they cannot perform an increasing number of tasks on their own, their perceived self-efficacy may decrease. Consequently, the teachers need to develop methods to replace the methods they use in the classroom to identify students with relatively low self-efficacy, and provide tasks which all the students are able to master individually or in groups with proper support.

Otherwise, the dropout rate at vocational schools and colleges could increase. This may be a serious problem, since just one out of twelve Danish municipalities complies with the current requirements relating to student dropout rates [16].

This problem was intensified by the fact that students also, in their own opinion, lose motivation as time goes on [13, p. 6]. For obvious reasons, many students reported increased needs for social contact during the closure of the physical learning environments. They generally missed social interaction with other students during the period of pure online teaching and learning events [11]. From day to day, they actually became less happy with their situation, which affected their motivation and industriousness.

Under these circumstances, teachers should consider more dialogical approaches allowing the students to ask questions and present their academic understanding and major results of their self-directed learning activities. Moreover, they should consider collaborative learning activities and peer feedback. There is research evidence suggesting that collaborative learning generally leads to a greater learning outcome than individualised approaches (Table 4).

Table 4. The effect of student collaboration [12]

Type of method	Influence (effect size)
Collaborative vs. individual learning	0.59
Average of all types of methods	0.40
Individualised teaching	0.22

In some situations, it is most appropriate for students to develop specific skills individually, but in many other cases, students may benefit from working together for three major reasons. First, collaborative learning can help reduce feelings of social isolation. Second, it can cause subject terms to become part of students' active vocabulary. Third, it can strengthen students' commitment and serious work because they feel obligated by their agreements with other students.

Accordingly, it is crucial that the teachers foster collaboration in student-centered activities. For example, the teachers could promote co-creation, dialogue and other kinds of collaboration by allowing the students to use digital learning platforms, social media platforms, Google Docs, Skype, Zoom, etc. Additionally, the students could prepare for lessons, perform tasks, and receive feedback in pairs or in larger groups. Moreover, they could exchange and comment on each other's draft assignments and the like.

6 Conclusion and Perspectives

The paper addresses two research questions: What were the main challenges of emergency remote teaching after the closure of classrooms at vocational colleges and upper-secondary schools in the spring of 2020, and how can teachers overcome these challenges in future?

The research findings provide evidence suggesting that the schools did not succeed in utilising the potentials of online learning during these circumstances. From a student perspective, there were shortcomings regarding announcements of learning activities, feedback, professional support, differentiation in teaching, and social contact.

Consequently, both teachers and students experienced reduced student motivation and increased monotony in their teaching and learning experiences. In particular, the students became mentally distracted and demotivated, or lost their sense of self-efficacy, due to an increased number of assignments, which they generally regard as more difficult than before the emergency remote teaching was introduced.

Therefore, the teachers need to coordinate their expectations regarding the students' daily workload and individual need for teacher support. In addition, the teachers need to provide clearer announcements and more formative feedback and support. This includes supporting students who experience learning difficulties and social isolation during emergency remote teaching.

Generally, the teachers need to be informed by data generated by their formative evaluation of students' perceived self-efficacy, learning challenges, collaborative work and social isolation if they wish to practice blended learning in future. Additionally, they need to be informed by important findings in school research. This includes information about the strengths of blended learning synthesising teacher-centered and student-centered activities, which has a greater positive influence on students' learning processes than pure online and pure classroom education.

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Analysis of Practical Examples of a Real-Time Online Class on Agriculture in Space, Using the Collaborative Learning Tool "Digital Diamond Mandala Matrix"

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Abstract. The effectiveness of our "digital Diamond Mandala Matrix (dDMM)" application on a real-time online class is shown based on the results of analysis of output by students. The dDMM application which is something like a mind map limiting words to nine plus a description field for explaining the whole of the dDMM data. We can easily view several dDMMs at a glance for comparing them with each other, so it is highly suitable for an online class where only one screen can be shared. In order to improve the effect on students' learning, the class was offered in an active learning style, so that it consists of pre-learning, a real-time online class with a lecture, and discussions based on the pre-learning using Zoom Meeting, and students' re-thinking based on the online class as post-learning. Students input data into the dDMM application as pre-learning dDMMs before participating in the online class, and then join the class consisting of a lecture and discussions based on the pre-learning dDMMs. They input data into the dDMM application as post-learning dDMMs after the online class. In order to investigate the efficacy of the dDMM application on real-time online class, we compared them statistically using the text data analysing tool KH Coder pre-learning and post-learning dDMMs, which are outputs by students. From the results, we found that post-learning dDMMs are improved from post-learning dDMMs due to the lecture and discussions in the online class. Therefore, the dDMM application is an effective tool in real-time online courses. We will improve the application by adding functions such as automatic grouping for supporting collaborative learning, with multilingual support.

Keywords: Online class · Diamond Mandala Matrix · Text analysis · KH coder

1 Introduction

The results and its analysis of a real-time online class using our collaborative tool "digital Diamond Mandala Matrix (dDMM)" are shown. The class was part of the course "Agricultural Informatics in Next Generation" (instructor: Takahiko Naraki, lecturer: Seiichiro Aoki, director: Shinzo Kobayashi, number of students: 50) offered in

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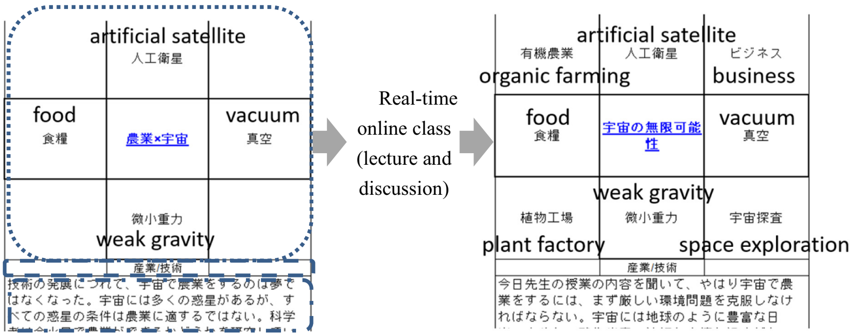
Japanese at The Kyoto College of Graduate Studies for Informatics (KCGI) in the Autumn semester of 2020. In order to improve the effectivity on students' learning, the class was offered in an active learning style. The class consists of pre-learning, a real-time online class with lectures and discussions based on the pre-learning, and students' rethinking based on the online class as post-learning.

In Japan, Diamond Mandala Matrix is sometimes used as a framework to realise "total optimisation of business and systems" in Enterprise Architecture (EA), which has been mainly worked on by the Ministry of Economy, Trade and Industry (METI). The advantage of DMMs is that cells are limited to up to nine [1] (comparable to a dotted line rectangle in Fig. 1a), so we can see all of the cells in a DMM at a glance. We thought DMM is highly suitable for online classes, so we have been developing a dDMM application inspired by DMM. In the class, we used the dDMM application for pre-learning and post-learning of students. In order to investigate the effectiveness of the dDMM application on a real-time online class, we compared and analysed the statistical output by students such as pre-learning dDMMs and post-learning dDMMs. dDMM data are text type data, so the analysis was performed using the free text analysing tool "KH coder" [2] as the first step of analysis. A similar analysis using KH Coder was performed by Aoki et al. (2020) for the answers to the questionnaire taken in astronomy lectures [3].

The dDMM application has been developed as a collaborative learning tool inspired by DMM. The dDMM application is used before a real-time online class consisting of lecture and discussion as pre-learning dDMM, and after the class as post-learning dDMM. The structure of dDMM can be seen in Fig. 1a. In the nine cells at the top (dotted line rectangle in Fig. 1a), a student input words in the surrounding eight cells and representative phrase in the central cell. In the three middle cells (dashed line rectangle in Fig. 1a), SDGs (Sustainable Development Goals) related to words in dDMM are selected. The bottom field (single dashed line rectangle in Fig. 1a) is a descriptive field for explaining the whole of the dDMM using words in the top nine cells. So, dDMM is something like a mind map that limits the number of words up to



(a) Pre-learning dDMM (b) Post-learning dDMM

Fig. 1. Examples of dDMMs created by a student. (a) Pre-learning dDMM. (b) Post-learning dDMM. A student creates a pre-learning dDMM before real-time online class and post-learning dDMM after the class.

nine, extended with SDGs labels and descriptive fields. SDGs labels were setup because the course was related to sustainable society. And the dDMM application is highly suitable for an online class, where a single screen only is shared using an online conference system. We can easily compare several DMMs through discussion, whenever only one screen can be shared using an online conference tool such as "Zoom Meetings".

In this paper, we show the effectiveness of the dDMM application on a real-time online class, by comparing pre-learning and post-learning dDMMs statistically.

2 Structure of Online Class

The main theme of the course was "Thinking about Sustainable Agriculture and Community". In the course, "Agriculture × Something = Sustainable Society" was set as the common theme (target scope) for all classes. Based on the target scope, we set up a subdivided scope (topics related to the target scope) in each class session. The scope of the class for analysis was "Agriculture × Space = Sustainable Society".

The classes consist of pre-learning, real-time online classes (lecture and discussion) and post-learning (see Fig. 1).

1) (Pre-learning) Each student found words related to agriculture in space by referencing websites, books or papers supplied by the lecturer, and input them in eight cells surrounding the central cell at the top of dDMM (see Fig. 1a). The phrase in the central cell was set to "Agriculture x Space," which was common to all students. In the bottom field, students input sentences explaining whole of the dDMM. Here, the pre-learning dDMM was completed. These tasks were done by each student before attending the real-time online class.
2) (Real-time online class) The real-time online class was offered using a Zoom Meeting. The first half of the class was a lecture, explaining the Sun, Mars, Europa, Enceladus, and other satellites and exoplanets, especially from the perspective of agriculture in space. In the second half, discussions were held on the subject of pre-learning dDMMs (lecturer: Aoki, facilitator: Naraki, director: Kobayashi).
3) (Post-learning) On the basis of the real-time online lecture and discussions, each student created a post-learning dDMM by investigating words related to agriculture in space one more time. In the central cell at the top, each student thought up a phrase that represents the words in the surrounding cells. The results of the analysis of the central cell will be shown in another paper.

In order to offer the classes, we used the following tools.

(a) digital DMM (dDMM) application: It can be used on a browser, so students can use it with either a PC or a smartphone.
(b) Online conference system: Zoom Meeting is used for real-time online classes.
(c) Learning Management System (LMS): dotCampus of KCGI was used to share course materials.

3 Results of Analysis Applied to dDMMs

dDMM data for pre-learning and post-learning created by a student are shown in Fig. 1. At the bottom field of the post-learning dDMM, we can see that "after hearing the lecture today, I understood that we must first overcome the harsh environment in order to farm in space" (see Fig. 1b). The overall difference between the pre-learning and the post-learning dDMMs is shown in the correspondence analysis diagram of words in the surrounding eight cells at the top (see Fig. 2). In the pre-learning dDMM,

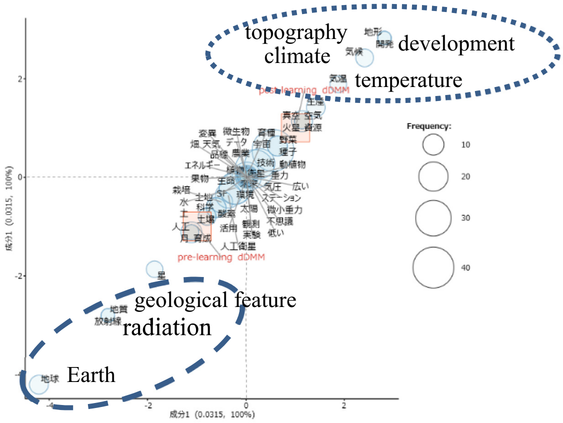


Fig. 2. Correspondence analysis diagram of the words in the surrounding eight cells of the central cell at the top in the dDMMs. Words that appeared four or more times are used. The words in the lower left (dashed line ellipse) are those appeared more times in the pre-learning dDMM relative to post-learning dDMM. The words in the upper right (dotted line ellipse) are those that ap-peared more times in the post-learning dDMM relative to pre-learning dDMM.

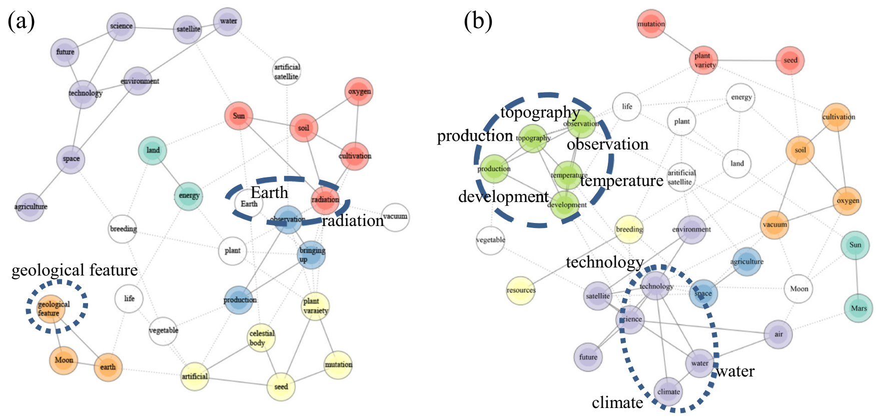


Fig. 3. (a) The co-occurrence network diagram of words in the surrounding eight cells at the top of the pre-learning dDMM and (b) that of the post-learning dDMM. The minimum number of appear-ances of a word is set to three. The darker the connecting line, the more students entered the words into the cells at the sametime.

"Earth," "radiation," and "geological feature" are more common, while in the post-learning dDMM, "topography," "development," "climate," and "temperature" are more common. From these characteristics, the perspectives of students about agriculture in space before attending the online class were with a point of view of an Earth-centered mind and the effects of radiation and geological feature, whereas after the class students got a broader perspective such as "climate," "temperature," "topography," and "development".

The co-occurrence network diagrams of words in the surrounding eight cells around the central cell at the top of the pre-learning dDMM and post-learning dDMM are shown in Fig. 3a and b, respectively. The connected words with lines are those which students put into the surrounding cells at the same time. Comparing Fig. 3a and Fig. 3b, we can see that the number of students who entered "Earth" and "radiation" (see dashed line ellipse in Fig. 3a) and "geological feature" (see dotted line ellipse in Fig. 3a) at the same time in the post-learning dDMM is decreased, because they are not appeared in the post-learning dDMM. On the other hand, the number of students who entered "topography" and "observation," "temperature," "development," or "production" (see dashed line ellipse in Fig. 3b) at the same time is increased. And the number of students who entered "climate" and "water" or "technology" (see dotted line ellipse in Fig. 3b) at the same time is also increased.

The overall trend of differences between the pre-learning and the post-learning dDMMs also can be seen in the correspondence analysis diagram of word in sentences in the bottom field of dDMMs (see Fig. 4). In the pre-learning dDMMs, "other" (other stars, other planets), "vegetable," "mutation," "growing," "science," etc. are more common, while in the post-learning dDMMs, "outside" (outside stars, outside planets, etc.), "growth," "water," "breeding," "necessary," etc. are more common. From these characteristics, it can be seen that before the online class, the students were aware of the

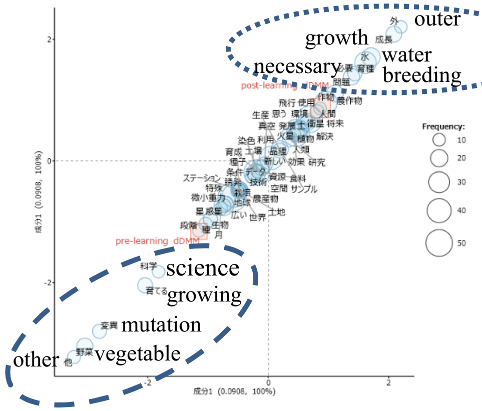


Fig. 4. Correspondence analysis diagram of the words entered in the bottom cell of the dDMMs. Words that appeared ten or more times are used. The words in the lower left (dashed line ellipse) are those that appeared more times in the pre-learning dDMM relative to post-learning dDMM. The words in the upper right (dotted line ellipse) are those that appeared more times in the post-learning dDMM relative to pre-learning dDMM.

genetic "mutation" of organisms due to the effects of radiation, and the use of "science" to "grow" crops such as "vegetables", while after the class students became to be aware of the active use of "breeding" and the "necessity" of "water" for "growth".

The differences are probably due to the fact that the lecturer took Mars as an example in the real-time online class, showing the low temperature and severe climatic conditions, the difficulty in getting water, and the topography line a desert. In addition, "breeding" was discussed between the students and the lecturer during the online class for active use of genetic mutations, which possibly led to the differences.

4 Summary and Future Work

It was shown that each student came to think more realistically about agriculture in space due to the real-time online class, because dDMMs were influenced by the topic of lecture and discussions, which was seen in the statical text analysis of pre-learning and post-learning dDMMs with the KH Coder. So, the dDMM application is an effective tool in a real-time online class, and its advantage is that several dDMM data can be easily compared on one screen. Here, the practical examples on online class were shown, but it is not an online-only tool, so it can also be used effectively on offline courses. The dDMM application can be also useful for writing a learning portfolio. In a course of computer networks, we assigned students to compile portfolios comparing pre-learning and post-learning dDMMs as evidence, in order to indicate what they learned in the course.

We have been developing the dDMM application as a collaborative tool, but we have not yet used it in online multiple groups, which is assumed in typical collaborative learning. We are considering implementing the dDMM application the function such as automatic grouping, based on pre-learning dDMMs to support collaborative learning. Then, we will apply it on a class with multiple groups to investigate its effects in collaborative learning. We have used the dDMM application in a paper-based style for group work in an offline class in a high school. But we did not undertake analysis because of insufficient data. We will also implement multilingual support using Google Translate for users whose native language is not Japanese. In addition, we have been improving the dDMM application adding a function to input images for symbolising the words in the top nine cells of dDMM. This function is very useful for elementary and junior high school students, who may not be good at verbalising their ideas.

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AsTRA – An Assessment Tool for Recognition and Adaptation of Prior Professional Experience and Vocational Training

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Abstract. Educational systems in most countries are differentiated by level and entail transitions between different school types. The different school types do not always support a transition without gaps or repetitions. For students, this can be very frustrating, demotivating and time-consuming. For example, many graduated IT specialists bring work experience, a number of relevant competencies and previous knowledge from their vocational education and training into a degree programme in computer science – yet they still have to take the associated courses and pass examinations. To improve this situation and value the competencies brought along, we implemented a project to develop a comprehensive system to honour the prior knowledge of these students in various ways. One of our goals is to promote permeability between vocational and higher education, not only in computer science. The core element of this System is AsTRA, a comprehensive assessment tool which we developed to evaluate the common learning content and its difficult level. This system is designed to credit previous knowledge and to adapt the students' learning paths, based on reliable decisions. In this paper, we present our tool AsTRA that supports these decisions as well as a brief overview of our resulting recognition system.

Keywords: Higher education · Vocational education · Adaptation · Permeability · Assessment · Assessment tool · Educational systems · IT specialist · Competence · Recognition · Recognition of prior learning · Study programme · Bachelor computer science

1 Introduction

All differentiated education systems have one challenge in common: Ensuring a smooth transition of students between the different parts of the system. In Germany, the education system is very diverse. Students can switch between different pathways in secondary education as well as in vocational and higher education. The latter two fields tend to compete rather than interact in many professional fields such as computer science. Therefore, students with general university entrance qualifications how have

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completed dual vocational training[1], e.g., as IT specialists (generally recognised apprenticeship), can take up higher education studies, but the competencies they have acquired during their apprenticeship are only partly recognised by the universities. This means that students like these IT specialists bring work experience, personal and professional competencies, and previous knowledge from their vocational education and training into a degree programme, for example in computer science; yet they still have to take all the associated courses and pass examinations.

Apprenticeships in computer science, such as IT specialists, are widely considered to be of high professional quality, and many IT specialists work hand in hand with academically educated computer scientists [1]. Furthermore, in a study addressing multiple training in terms of vocational education and university studies, Jacob [2] concluded that for many high school graduates, vocational education before university studies is not considered a detour but has a value of its own. In the students' perceptions, university studies subjectively build upon vocational training in their specific field of study [2, p. 156].

Nevertheless, the universities hardly recognise competencies acquired in vocational education or during a professional activity. Crediting more than a few modules fails due to knowledge about the extent of overlap between vocational and higher education [3]. Universities argue that vocational training is located at level four of the DQR ("Deutscher Qualifikationsrahmen für lebenslanges Lernen")[2] [4] – the national implementation of the EQF (European Qualifications Framework)[3] [5, pp. 82–83] – whereas bachelor modules (duration: 6 semesters) are classified at level six. This difference in levels, as well as the different focus (professional vs. academic education), makes the implementation of permeability concepts between vocational training and university studies challenging. On the other hand, increasing permeability between these vocational education and training and academic education has been on the agenda in education politics for some time now (cf. [6]).

For this reason, we started a project that introduces and systematises the *formal recognition of professionally gained competencies of IT specialists in computer science as a prototype* and thus, promotes comprehensive permeability between vocational and academic education as a first example for such a general recognition system. Our tool AsTRA is an essential part of this project. It is an important result as well as an important tool for further use.

2 Foundations of the Project

2.1 Formal Recognition of Former Competencies in Higher Education

At later stages of their career, some of the professionally trained individuals go on to professional further training or study at university to gain additional competence and to

[1] *Completed dual vocational training*: students attend vocational school for their profession and are paid apprentices of their training companies for 3 years. The dual vocational training ends with a final examination approved by the state.

[2] https://www.dqr.de/content_en/home.php.

[3] https://europa.eu/europass/en/european-qualifications-framework-eqf.

achieve a degree. They do so for better progression and promotion in their professional development. Some of these students continue to work in their company and take up part-time studies, often at distance learning universities such as FernUniversität in Hagen.

This professional development path is relatively common for IT specialists who bring several competencies as well as professional experience and previous knowledge into their studies. But their competencies are usually only credited and recognised with credit points (CP) selectively by the universities (cf. for example in the context of the NEXUS[4] or the ANCOM project[5] [7]). However, crediting previously acquired competencies, qualifications, and skills is a key element in the transition from a vocational training path to university studies. Hence, in 2002 the “standing conference of the ministers of education and cultural affairs” (KMK) put a resolution into effect to promote a smooth transition by *formal recognition of previous gained competencies* [8, 9]. The various projects (e.g., [10] or [11]) of this initiative have not yet achieved a broad impact. One factor is the academic self-image of the universities, which want to maintain the academic nature of the studies. Another reason for the missing impact could be that universities and other higher education institutions rely on the elaborate judgement of experts (such as professors) when it comes to questions of recognition (cf. [12]). These experts then decide according to their respective expertise. The sole assessment by one person can bias the recognition decision since it is influenced by the individual attitude towards recognition in general and other conscious or unconscious factors. That means that existing recognition systems lack a decision-making process based on transparent, reliable, and binding criteria [13, pp. 60–61] that can be understood by others (cf. [14]). This situation is unsatisfactory because transparency and reliability are quality criteria in the context of recognition [15, p. 238] and will therefore be addressed explicitly.

In our project, we base the recognition system on existing recommendations for higher education in computer science [16] as well as on facets of existing competence models for IT specialists [17, 18] and computer science education. For example, the MoKoM project group (e.g., [19, 20, pp. 77–96]) developed a comprehensive competence model for computer science. For this competence model, the researchers implemented competency level tests with several facets. They defined different knowledge dimensions, the level of connectedness, combinatorial complexity, and the level of the necessary understanding of systems of computer science [21, pp. 199–216]. Although this model was developed to measure individual competencies, some of the different parameters could be used to generally evaluate the levels of competencies gained in vocational education. Other competence models focus on general education – such as the KUI model [22] – or address only certain aspects of computer science like OOP [23] or privacy [24] and are thus not suitable for direct use in our project.

Therefore, an important part of our project is to develop a reliable, transparent, and comprehensible tool to evaluate and assess prior skills and competencies – to become more or less independent from expert ratings.

[4] https://www.hrk-nexus.de/projekt-nexus/information-in-english/.

[5] http://ankom.dzhw.eu/know_how/anrechnung.

2.2 Research Questions

Although the project aims to develop and evaluate an exemplary recognition system to promote permeability for IT specialists at FernUniversität in Hagen, the aim of the project part presented in this paper is to develop a tool for assessing the equivalence between the prior knowledge and the competencies to be acquired at higher education. The tool will initially be used for the transition from IT specialist to the bachelor programme in computer science. After successful evaluation, it will gradually be used for other professions and degree programmes.

Considering the current situation of formal recognition for vocational education, the following questions arise:

1. How can competence descriptions from vocational education and training be systematically and comprehensibly compared with those from higher education?
2. What would a system or a tool look like that would support this comparison?
3. How must an assessment tool be designed so that it can make statements about the equivalence of competencies without in-depth expert knowledge?

To answer the research questions, we implemented the interdisciplinary research project called "Permeability"[6], which we describe in Sect. 4. Within the framework of this research project, we developed the tool AsTRA as an answer to these questions.

2.3 General Approach

We use methods from design science (cf. i.e. [25]) and develop the planned recognition system by a cyclical approach. In this approach, we develop several process flows that will be used to implement and later to manage a comprehensive recognition system. These process flows will also be evaluated, further developed, and validated in several cycles while implementing them into a functioning system at FernUniversität in Hagen to support our students.

As previously described, one of our aims is to reduce the influence of expert assessments on the recognition decision by developing clear guidelines and decision-making aids. Our solution, a comprehensive system to assess and compare competencies from different education systems will be presented in the next section.

3 *AsTRA* – *As*sessment *T*ool for *R*ecognition and *A*daptation

Our guiding questions are how to recognise the right competencies and how to support the students by enabling them to study more efficiently. To recognise the right things, we needed a tool to assess and compare competencies described in the official documents from vocational education with our bachelor programme. To master this challenge, we required a system to translate and compare the difficulty and complexity of both education systems within the DQR (IT specialist: DQR level 4, bachelor programmes in higher education: DQR level 6). Although the level description verbs of

[6] https://e.feu.de/permeability (in German).

both DQR levels are based on the taxonomy of Anderson & Krathwohl (AKT) [26], it must be examined to what extent the actual DQR level descriptions correspond to each other.

Furthermore, the German vocational education system's regulatory documents are based on a work process and competence-oriented description (e.g., "Apprentices develop and extend software components"). Competence has been defined as "vocational action competence" which includes the facets of professional and personal competence [27]. In contrast, similar documents for higher education have a subject logical structure (e.g., "Introduction to theoretical computer science" or "advanced aspects of operating systems"). For this reason, we assume that "*competence in the field*" (work experience, ability to contextualise theoretical knowledge and skills) is a fundamental differentiation criterion between an IT specialist and a computer scientist from university. This means, that questions arise whether, e.g., "they *implement* programmes in a high-level programming language" (competence model for IT specialists [17]) has an equivalent meaning both in vocational and academic education. Or – more abstract – what conclusions can be drawn from a possible equivalence in the *learning contents* as well as in the *level of the educational programmes*.

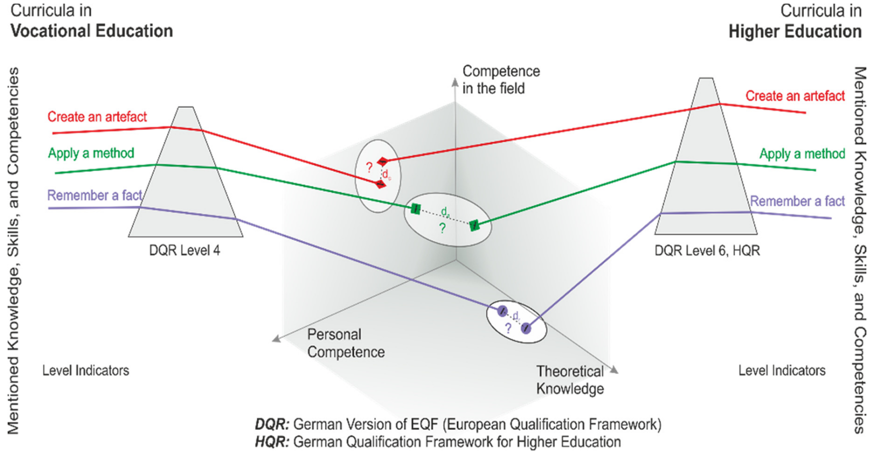

Fig. 1. AsTRA development approach: conceptual idea of matching knowledge, skills, and competencies from vocational to higher education in computer science.

3.1 Development of AsTRA

In the context of recognition "equivalence" does not mean "equal". However, a general definition of this equivalence does not exist. Therefore, we developed such a definition by including several aspects and dimensions:

The DQR proposes *professional knowledge and competency* as a key aspect. Another facet that should be included is *personal competence* (e.g. the competence to organise oneself, to work independently, to work and communicate in teams). As we see "*competence in the field*" as a differentiation criterion, this should be the third aspect. The latter is a combination of experience, professional knowledge, and personal competence. Hence, this aspect is orthogonal to the other two. This results in our 3-dimensional model to assess the inherent equivalence of both educational systems, which can be seen in Fig. 1.

Based on this first model concept, we discussed the possible implementation. We assume that a typical task on a certain level has typical characteristics in both vocational and higher education contexts. These characteristics can be seen each as a triple of values which defines a point in the 3-dimensional model. The open question at this stage is, what is the decision criterion? Is it enough to evaluate the distance d between the points, or does the mutual position of the points in relation to each other also have to be evaluated? This question is a fundamental part of the development of our tool named AsTRA.

As depicted in Fig. 1, we decided to develop a system that translates the AKT level indicators between the two education systems. It became apparent soon that in the first step, we should develop this transfer system based on a specific module. As the module "*Introduction into Imperative Programming*" is a promising module for recognition, we decided to use it as the prototype. Thus, we analysed several documents and sources of information:

The formal documents from vocational education such as *curricula* and *formal training regulations* have a low granularity. Therefore, we used an existing competence model for the profession of IT specialist [17] which we improved by analysing further information gained of previous final examinations. Furthermore, we took a close look at the *module descriptions* and *exercises*. Especially the module descriptions are not always detailed and precise. For this reason, we also analysed the course texts and the several exercises and quizzes which have to be mastered by the students.

As a result, we obtained a comprehensive and structured list of learning outcomes – represented by a level description verb and a learning content noun – with different granularity from both education systems. These statements allow the mapping to the AKT levels and therefore a more precise comparison of competencies. The list contains statements such as "IT specialists *extend* existing software with customer-specific functions or interfaces" or "IT specialists *implement* source code for small problems" from vocational education as well as "students *master* small programming tasks" or "students *complete* a given programme according to specification" from university level. The challenge here is that the content areas are similar, but sometimes very different level indicators are used. For example, in vocational training, the statement "IT specialists *develop* algorithms and functions for processing given lists" can be found, while in the bachelor programme the competence "they *use* simple dynamic data structures such as linear lists" has been described. Although these two competencies are different in terms of level, they refer to the same area (data structures/lists). The question of equivalence can therefore not be decided by looking at individual characteristics and statements alone, but the entirety of the contents of the training and the modules under assessment, and their level must be considered.

Therefore, we postulate that equivalence can only be achieved if there is first equivalence in terms of content (necessary but not sufficient criterion). Only then can equivalence be assessed by evaluating the level in the second step. Hence, we developed AsTRA in a way that each assessment consists of two stages:

First Stage: Content Analysis. To assess whether the content and level of vocational education and training as IT specialist is equivalent to the module "Introduction into imperative programming", we first used AsTRA for a content analysis. We grouped the statements of both education systems by content areas such as "testing", "modelling", or "implementing and programming" (see Table 1). We found that all content areas from university studies are also part of the apprenticeship as an IT specialist. Moreover, the content priorities are similar in both programmes. Areas such as software ergonomics, documentation, data security and data protection are not addressed in the module but are part of the training. Only one single aspect from the module is not part of the vocational training, namely recursion, which is not a core aspect of the module. Therefore, we assume equivalence in terms of content.

Table 1. Content analysis: content areas in the module "Introduction into imperative programming". The numbers show the ratio of statements in each area. Total: 40 statements for IT specialists, 45 statements for the university module.

Content area	IT specialist	University module
Modelling concept development	10.0% knowl., 20.0% skills	4.4% knowl., 0.0% skills
Software ergonomics	2.5% knowl., 2.5% skills	–
Implementing and Programming	0.0% knowl., 45.0% skills	4.4% knowl., 73.3% skills
Testing	2.5% knowl., 5.0% skills	2.2% knowl., 15.6% skills
Documentation	2.5% knowl., 5.0% skills	–
Data security and Privacy	2.5% knowl., 2.5% skills	–

Second Stage: Level Analysis. The DQR classifies a finished bachelor programme at level 6. Students reach this level step by step. For this reason, we first introduced a *level translation* for modules. We assume that students start their studies at level 4 on average, because the vocational baccalaureate diploma as university entrance is also located on this level. By acquiring credit points and gaining competencies, they reach level 6 at the end of their bachelor studies. Our exemplary module is located in the study entry phase, and we assume that students reach a maximum of DQR level 4.5 in the first year of study. We further assume that after second year of study, students reach level 5, and after the third year, they finally reach level 6. We define this value as *relative module complexity* (cf. Fig. 2).

Vocational Training — DQR 4 | Relative Module Complexity: 4,5 | **Bachelor Programme** — DQR 6

DQR 4	Complexity Adjustment Factor: Theoretical Experise	Complexity Adjustment Factor: Personal Competence	Complexity Adjustment Factor: Competence in the Field	Absolute Complexity: Theoretical Experise	Absolute Complexity: Personal Competence	Absolute Complexity: Competence in the Field	Overall Indicator (2:1:2)
Creating	0	0	1	4	4	5	6,00
Evaluating	1	1	1	5	5	5	6,71
Analyzing	1	0	1	5	4	5	6,57
Applying	0	0	1	4	4	5	6,00
Understanding	0	-1	-2	4	3	2	4,22
Remembering	-1	-2	-2	3	2	2	3,35
Weighted vector length for each level							5,475

Overall Indicator (2:1:2)	Absolute Complexity: Theoretical Experise	Absolute Complexity: Personal Competence	Absolute Complexity: Competence in the Field	Complexity Adjustment Factor: Theoretical Experise	Complexity Adjustment Factor: Personal Competence	Complexity Adjustment Factor: Competence in the Field	DQR 6
5,33	4,5	3,5	3,5	0	-1	-1	Creating
5,33	4,5	3,5	3,5	0	-1	-1	Evaluating
5,33	4,5	3,5	3,5	0	-1	-1	Analyzing
5,33	4,5	3,5	3,5	0	-1	-1	Applying
4,86	4,5	3,5	2,5	0	-1	-2	Understanding
4,01	3,5	2,5	2,5	-1	-2	-2	Remembering
5,03 (Unweighted mean of level vector lengths)							

Fig. 2. AsTRA – Level translation of the module "Introduction into Imperative Programming". The overall indicators for each AKT level on both sides are weighted to give more weight to professional than to personal competencies. The overall mean was calculated unweighted over all AKT levels.

The next step was to estimate a *complexity adjustment factor* to consider both the individual difficulty and requirements of the module and the working field in apprenticeship. This is the only step that only depends on the inherent knowledge and experience of the assessing person. In our example, to master the basic programming module, students need only little personal competence or competence in the field – so the adjustment factors lower the absolute complexities of each AKT level for these factors. The resulting triples of absolute complexities describe 3-dimensional position vectors in the coordinate system of Fig. 1. Calculating the (weighted) lengths of the vectors provides an *overall indicator* for each AKT level (see Fig. 2). Comparing only the length seems sufficient in the first development cycle, as the position vectors are very close to each other and therefore the absolute length is sufficient as a criterion. A refinement including the position is planned for the next development steps.

The learning content from vocational education is rated as more complex and on a higher DQR-related level in this case. To improve this first result, we evaluated the statements of the content analysis again. We subsequently calculated the (relative) complexity of each AKT level (see Fig. 3), which also takes the relative frequency of the different level statements into account. As a result, we obtained a complexity level, based on the weighted number of statements from the content analysis and the overall indicator of the module respectively the professional working field. In our first application, we defined equivalence if the deviation between the scores is not more than 20%, referred to the complexity of the university module.

Level Analysis	**Bachelor of Science in Computer Science**	**Level Correction Factor**	
Module:	**Introduction to Imperative Programming**	Study Entry Phase	-1,50
		2nd Year	-1,00
Role in Study Programme:	Study Entry Phase	Final Phase	0,00
Complexity of Module:	4,50		

Proportion of level operators in the overall result:

Level	Number of Statements: Vocational Education	Number of Statements: Module	Ratio: Vocational Education	Ratio: Module	Complexity: Vocational Education	Complexity: Module
					*Weighted Vector Length * Ratio*	
6	5	0	13%	0%	0,75	0,00
5	2	5	5%	11%	0,34	0,59
4	11	8	28%	18%	1,81	0,95
3	11	26	28%	58%	1,65	3,08
2	4	1	10%	2%	0,42	0,11
1	7	5	18%	11%	0,59	0,45
Complexity Level based on the weighted number of statements in table "content analysis":					**5,55**	**5,17**
				Calculated deviation	*7,30%*	

Fig. 3. AsTRA – Level analysis of the module "Introduction into Imperative Programming". The complexity of the contents from vocational education in this field is higher than of the resp. module. The calculated deviation has been based on the (relative) complexity of the module.

3.2 How Can AsTRA Support Recognition?

We used AsTRA in this version for all modules that have been promising due to expert judgement to analyse for our project. We compared the results with several expert ratings and found only little need for change in our model at this stage. This tool allows us to evaluate whether or not a module could be credited by recognition. It also helps to support the development of adapted teaching material and to identify gaps in competencies reported by our students for individual recognition. Currently, we use AsTRA to evaluate courses and modules, and as a further step we plan to apply it also for the analysis of study programmes. Furthermore, AsTRA helps us to ask the relevant questions, such as 'is it appropriate to adapt this teaching material for all students of a cohort (like IT specialists), because we can assume that most students already have certain competence?', 'does it make more sense to adapt the courses for the individuals?' or 'are there key aspects for individual recognition of a module we should take care of?'. In the next section we show how the implementation of the tool moves the project forward by using and evaluating it.

4 Structure of the "Permeability Project"

In our project, we defined *three pillars of recognition* to promote reaching our goal to create a comprehensive recognition system.

First Pillar – Blanket Recognition: For this recognition, students have only to submit their training certificate from their completed vocational training as IT specialist to the examination office. Assessing our course modules with AsTRA, we identified "*Introduction into Imperative Programming*" (5 CP) to be recognised on-demand for all these students, and "*Basic Training in Programming"* (10 CP) from the second study year for IT specialists in application development.

Second Pillar – Individual Recognition: This can be applied to all modules whose learning content is not or only partially part of the vocational training. The procedure of individual recognition is an assessment of individual cases to acknowledge and recognise non-formally and informally acquired competencies with up to 20 CP by assessing a portfolio written by the students.

Third Pillar – Adaptation of Learning Pathways: Using AsTRA, we found several modules (e.g., "*Databases*", "*Operating Systems & Computer Networks*" or "*OOP*") which have an overlap in learning content and level with vocational education. This overlap is not enough to recognise the whole course. Therefore, we offer the opportunity to use adapted (digital) course material that allows the students to design their learning pathways by getting recommendations for their next steps based on their prior knowledge. In this way, students can thus study more effectively by only working on the content that is new to them.

5 Conclusion

The tool named AsTRA that we presented in this paper is an essential part of the "Permeability Project" which scrutinises the permeability between vocational and academic education systems. We found that competence descriptions from vocational education and training, and those from higher education, can be systematically and comprehensibly compared by mapping them to a metric space and then calculating the distance. This has been implemented into our tool AsTRA that allows us to assess the previous competencies of students based on transparent, reliable, and binding criteria and formulae. It therefore provides the possibility to create a transparent, reliable, and comprehensive recognition system that has been practically implemented in Winter 20/21. Further work will show how we can deal with students who bring lots of competencies into their studies – but competencies that do not match our modules, for example because the students are physicists, or engineers, or something completely different.

So how can we value and recognise these competencies? To do that we need an approach that goes beyond our three-pillar model and AsTRA. Our intention is to formally value further competencies. For this reason, our future question is, what constitutes a degree programme and what role do individual modules play in the various degree programmes?

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Is It Real? – Learners' Perceptions on Tele-Immersive 3D Video Technology and Its Further Use in K-12 Education

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Abstract. Current immersive technology applications, such as virtual and augmented reality (VR/AR), are still limited in providing an immersive experience in which a user is perceived in 3 dimensions (3D) as their real self. Furthermore, research on such immersive environments applied to educational contexts is scarce. To investigate the unexplored opportunities of immersive technologies in education, we carried out a trial of our tele-immersive platform (TIP) with elementary school 6th grade learners (12–13-year-olds) working on an environmental study lesson. During our investigations, we applied qualitative analysis of the learners' focus group interview, researchers' field notes, and recordings of test sessions, alongside descriptive statistics of questionnaires. Learners expressed feelings of positive surprise and excitement, and felt the technology enabled their participation throughout the lesson. Learners recounted feelings of 'being there' inside the environment, and in the company of the teacher. Learners agreed that their sense of physical proximity and presence inside the immersive environment is similar to that of face-to-face interaction with the teacher. With our investigations, the opportunities of this emerging technology towards boosting online educational activities for learners to develop their 21C skills are highlighted. Our findings indicate that the introduced 3D TIP technology has the critical potential to overcome psychological strains due to physical distance in online education.

Keywords: Sense of presence · Immersive learning environments · 21C skills

1 Introduction

The outbreak of the Covid-19 pandemic since 2020 has rapidly increased the demand for online communication in education. We see the use of online platforms ranging from asynchronous email, online discussion boards, and blogs, to synchronous video conferencing, text messaging and Voice-over-IP services (in which the learners and instructor are together online at the same time) as well as hybrid formats combining different forms of media (e.g., text, audio, video) and different timescales (e.g.,

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asynchronous, synchronous) within the same meeting [1]. Technologies such as virtual (VR), augmented (AR) or extended reality (XR), might be used to create more realistic group encounters for distance learning and online collaborative activities, for instance. In this vein, immersive learning environments expanding traditional VR or telepresence are emerging as a suitable solution for supporting novel forms of online collaboration and practices [2, 3]. Nevertheless, the fast demand for the development of immersive technologies in educational practices is ridden with limitations that can be addressed at the design stage, through the involvement of students and teachers throughout the design process, as advocated by co-design [4]. Still, there remains insufficient evidence about the effect of immersive 3D video technology on an overall sense of presence or on key factors related to learning [3].

In previous work, in which primary school children collaborate across national, regional, political and cultural boundaries in the same immersive virtual learning space, Rötkönen et al. (2019) [5] reported concrete suggestions that the learners provided for improvements, including the use of real faces rather than drawn avatars, and their wish to meet, get to know each other, talk, shake hands, play and be together in the virtual environment as normally as they act in real life.

To further investigate this matter, we have designed and implemented a live 3D tele-immersive platform (TIP) - an environment for K-12 education providing an immersive three-dimensional alternative to video. TIP integrates novel 3D video technologies, within which the teacher can be perceived in 3 dimensions, generating a sense of being with a real-life person, instead of an avatar. In our prototype, rather than using immersive virtual environments, real environments are digitally captured live to form a high-fidelity model of a physical space and its occupants.

Extending the work of Rötkönen et al. (2019), our study is, therefore, a preliminary investigation of the experiences and sense of presence that TIP technologies can generate. We are seeking for signs of the potential positive effects of the TIP technology, as well as identifying the main challenges the technology presents in online educational contexts. Hence, this paper investigates further the opportunities and challenges in relation to the *sense of presence*, *technology* and *education* that is perceived within our TIP prototype during an online learning activity for elementary school children. We believe this kind of technology is very promising for creating and supporting novel forms of collaboration and practices for students and teachers during distance, as well as hybrid, learning activities. Our research questions, therefore, are:

RQ 1) *What are the perceptions of the learners towards the new 3D telepresence technology for education?*
RQ 2) *What impact does the new 3D telepresence technology currently have on the learners' sense of presence?*

2 Related Work

Information and communication technology (ICT) tools are now mainly used in schools in traditional ways to communicate, create, disseminate, store, and manage information, for instance, which has been reported to undermine the potential by which technology can reform the education realm [6]. However, as new pedagogical approaches emerge, aided by ICT tools, there is a change in education from the traditional teacher-centred classroom to a collaborative learner-centred classroom where learners can be actively engaged in the educational process, and knowledge, skills and attitudes are constructed and distributed in a collaborative way. Furthermore, the trend of the 21C towards a globally connected world, facilitated by the access to online technologies, has also had a profound impact on developing online collaborative learning as a new paradigm, connecting learners globally beyond the classroom. When learners are geographically dispersed, online technologies can be used to create connections and communication for sharing ideas and to co-create new understandings with others, making the local connect with the global, and learning happens in interconnected situations, utilising online technologies [7]. The utilisation of ICT is a way for learners to develop 21C skills [8], to prepare them as global citizens. Thus, under the collaborative learning paradigm, a future school needs to be equipped with people, tools and partnerships that allow the school to support its learners and local communities to act in the world, to set problems and solve them, extend their curiosity and to act upon it from a global perspective [9].

In order to support online collaborative learning and connect globally, emerging immersive technologies may provide functional solutions, since they can support the user to perceive each other in a natural way inside an otherwise virtual, or digitally generated, environment. For instance, VR applications can enhance learning and advance social and creative skills, and the use of them in learning situations seems to improve digital-age interactive literacy, creative thinking, communication, collaboration and problem-solving ability, which constitute 21C skills [10]. However, currently available educational technologies, such as e-learning tools, or traditional VR platforms, such as Second Life and Active Worlds, do not offer realistic learning experience environments, as these technologies are not able to replicate the perception of presence, a sense of "being there" with another person as in real life, which is vital for providing close-to-real-life experience and interactions. Social interactions are particularly important in K-12 educational contexts [11], as peer learning and socially constructed knowledge have been demonstrated to be fundamental for the socio-cognitive development of the learners in that age.

However, the concept of *presence* is very broad and has a variety of definitions and meanings. In our study, we look at the *sense of presence* in three dimensions: *presence* can offer insights into the medium's ability to provide the feeling that the user is "there" inside the media (*telepresence*), as well as in the "company of others" (*copresence*). At the same time, *presence* can measure the extent to which people feel that the interface is able to provide some sense of access to another's mind and connect people (*social presence*) [12]. Presence has been recognised as a key performance goal for many systems e.g., social presence as direct contributor to the success of the educational experience [13]. However, it is still a complex task to evaluate presence in an objective way [14]. To our knowledge, there is yet no known work on measuring a sense of presence of 3D video technologies with children. Moreover, there is a challenge that the questions of existing data collection mechanisms are difficult for children to answer, due to them being targeted at adults (and in our case, also language translation being required).

In the research area of technology use to support computer mediated collaboration, there is now an increasing, but still limited, amount of work towards synchronous telepresence technologies in education. Asynchronous collaboration tools have been receiving more attention [15]. In terms of applications of live 3D capture technology in education, there has been little if any progress since a few early trials [16, 17]. There is an abundance of work on immersive virtual learning environments or Collaborative Virtual Environments (CVEs), but not on 3D tele-immersive capture technology [15]. To our knowledge, there are currently three broad approaches being taken in industry and academia to achieve real time hyper-realistic 3D representation of people and spaces: a) Microsoft "Holoportation" or similar depth map fusion technologies [18]; b) Facebook "Codec Avatars" generated using machine learning; and c) dynamic reconstruction using only a single camera [19, 20]. Our own solutions at the University of Turku fit within category (a) currently.

The focus in the literature remains technical in nature, with little pedagogical evaluation and a very narrow view of the future potential. Moreover, there is little research on the pedagogy needed to make full use of the technology in K-12 education, and there is limited understanding of the affordances it may offer [3]. Our 3D TIP technology can be considered as a strong candidate to meliorate the shortcomings found in online technologies when applied to K-12 connective learning and education. In this paper, therefore, we present opportunities and challenges of a TIP prototype, towards its relevance in fostering a sense of presence among the learners that participated in our study.

3 3D Tele-Immersive Platform Prototype

In our study we use an in-house developed live 3D tele-immersive video platform (TIP). Our prototype setup consists of 6 stereo pairs of cameras, each pair connected to a desktop computer with a GPU (NVIDIA GeForce RTX 2080) for depth processing. The cameras are arranged around the edges of the room or group to passively capture the scene without intrusion. Once the depth data is captured from each camera, the camera views are merged together using camera pose information gained through a calibration step, to achieve a high-quality fusion with reduced noise distortion and errors in the different individual depth estimates from each camera.

Following fusion, the data are compressed as regular videos, using hardware for real-time performance. After transmission, the multiple video feeds for colour and depth are decoded, compression artefacts are filtered, and then arbitrary 3D views can be rendered locally using a straightforward point-cloud or mesh rendering combined with reprojection to the colour video feeds to add texture. Additionally, virtual objects, including live screen captures placed on walls or tables, can be mixed into the final scene. The overall latency of our prototype is around 200 ms, allowing a two-way experience where each physical space is captured and transmitted to the same web server. A viewing client can then obtain the data of multiple spaces and merge them together during the render step. The rendering is then viewed via a computer 2D display (using a web browser or an Open GL renderer), via an AR/VR headset or via a mobile phone.

4 Study Methodology

Our work is framed within a pragmatic research paradigm and is using research through design as a methodology [21]. This methodology states that research may develop not only through increasing agreement, but also through discursiveness and elaboration. Thus, rather than making statements about what is, the design aspect of the research is concerned with creating what might be [22]. In order to understand the applicability of 3D immersive video technology in real educational settings, we carried out testing sessions of an in-house prototype system together with learners, teachers and researchers. The prototype testing was designed to allow measuring the sense of presence that the technology fostered in the learners. As such, this study is framed within the following hypotheses:

H1: *The perceptions of the learners on the use of 3D immersive video in education will be positive (RQ1).*
H2: *Immersive 3D video technology will foster a high sense of presence in the learners (RQ2).*

4.1 Participants

Fourteen learners (6th grade, 12–13-year-olds) at one elementary school in Finland were chosen via random selection and given the opportunity to participate in testing our 3D tele-immersive video technology prototype. The elementary school involved is governed and financed by the municipality. Written permission was obtained from the parents or guardians of all participating learners, and the learners were also informed at the beginning about the nature of the research. Some learners had previously participated in research studies on unrelated VR technologies with our university. A single teacher at the same school was involved in the prototype testing and the learners knew the teacher well.

4.2 Experimental Setup and Testing Sessions

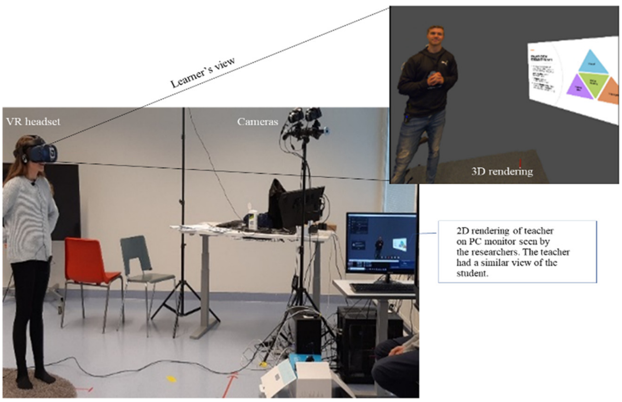

Fig. 1. Experimental setup, learner's view, and 3D rendering (Calkin Suero Montero 2021©, reprinted with permission)

During testing, the learners were in the school whilst the teacher was in another physically separate space off site, at our university facilities. The system was set one-way so that the digital view of the captured physical space where the teacher was located was received by the learners using an AR/VR headset (see Fig. 1). The teacher viewed the learners via a 2D display of a client computer using GeForce 1050+ and OpenGL renderer. This implementation was used in order to test a suitable trade-off between the system affordances, the costs of implementation, and the beneficial outcome of using this type of emerging technology in education from the learner's perspective (the learners are the ones that observe the teacher in 3 dimensions inside the immersive environment). Two researchers and a single video camera were located with the children to record the activity. The digital view of the VR headset viewpoint was recorded also for analysis. The 3D data was also recorded in addition to the video view of the participant. Between each participant, the equipment was disinfected due in part to the ongoing pandemic.

Each session with each learner lasted for approximately 20 min of which 10 min was the activity using the technology. After entering the testing room, the learner filled in a pre-questionnaire on the computer. The learner was then given brief instructions how to use the immersive 3D video prototype. After this, the learner was set to work on an educational activity together with the teacher within the virtual environment. The educational activity was a typical environmental study lesson related to the different kinds of fire, a subject that they had covered in their previous academic year and the instruction by the teacher was done by exploring the topic with the learner synchronously using a whiteboard. Each learner was assigned a random number which they then used to identify themselves to the observers and in their survey responses. Immediately following the learning activity, the learner answered the presence questionnaire using an online survey tool.

4.3 Data Collection

A presence questionnaire, researchers' observation, video analysis, and focus group interview were used to investigate the hypotheses. The questions in the questionnaire were translated into Finnish by an experienced teacher to ensure they were phrased appropriately for the learners in their native Finnish language. The measures used included *the Temple Presence Inventory* [23] *the Networked Minds Questionnaire* [24] *and the MEC Spatial Presence Questionnaire* [25]. The sessions as well as the digital view of the VR headset viewpoint, the 3D data and the video view of each participant were recorded for analysis. Two researchers were located with the learners to record the activity by taking field notes. The observations helped the researchers notice, identify, and understand different types of practical challenges that are faced during the sessions. After all the sessions were conducted a focus group interview was arranged with the learners. The purpose of the focus group interview was to deepen our understanding on the issues that were found from the observations. The interview protocol consisted of inquiring about the learners' feelings and experiences, feedback, and evaluation, as well as suggested improvements.

5 Results and Analysis

The recordings and observation notes thereof from the sessions, together with the interview transcript were content analysed. We used an inductive approach to thematic analysis [26] which resulted in three themes: *sense of presence perceptions*, *technology perceptions* and *educational applications perceptions*. Here, we present these three key themes and discuss opportunities offered and further challenges to address in relation to the use and development of 3D tele-immersive video in educational contexts, also answering the hypothesis set in the study.

5.1 Sense of Presence Perceptions

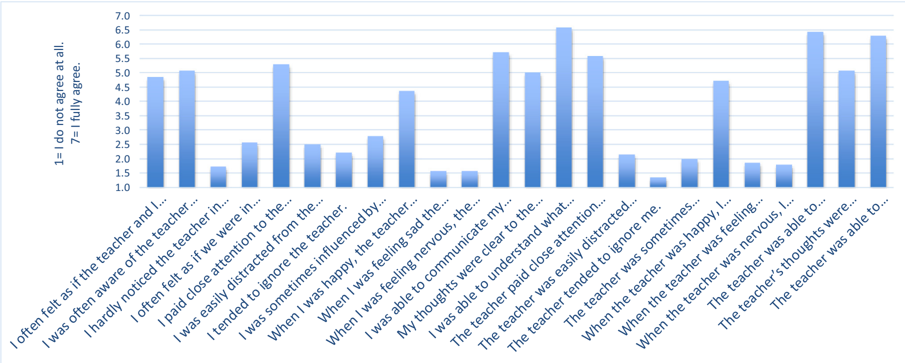

Fig. 2. Social presence questionnaire (descriptive statistics)

In relation to a sense of presence, from the social presence perspective, the learners reported that they highly perceived the teacher being immersed in the environment together with them (telepresence) also being easy to understand the teacher's expressions and ideas as if they were physically close (copresence), (see Fig. 2). For instance, item 2 (Q2), *(I often felt that the teacher was in the same space as me)* had an average response of over 5 on a 7-points Likert scale (1 = completely disagree | 7 = completely agree), while questions 3 (*I hardly notice the teacher in the space*) and 4 (*I felt as if we were in different places*) had an average score of 2.5 or below. Similarly, items 14, 22 and 24 related to the perception of understanding between the teacher and the learners had a high average response of 6 and above, indicating that it was easy for the students to understand the teacher's expressions and meanings within the virtual environment. This validates our H2 (also providing answers to RQ2).

The learners said in the focus group interview they had a feeling of being in the actual environment themselves and in the same space as the teacher, as indicted by the following quote: "*... and it felt as if* [I was] *in the same place with the teacher. I didn't* *even notice that I was wearing the glasses.*" (Girl2). Furthermore, the learners reported that it was not really important for them whether the environment contained errors or contradictions in order to work on the lesson: "*I looked around in a way so how the place looked like,…, looking.., like, where you are and all… like, What's in here?*" (Boy1 and Boy2). In general, the learners paid attention to the teacher, his voice and body expressions and gestures and they understood what the teacher meant during the lesson, which shows good potential for an educational application.

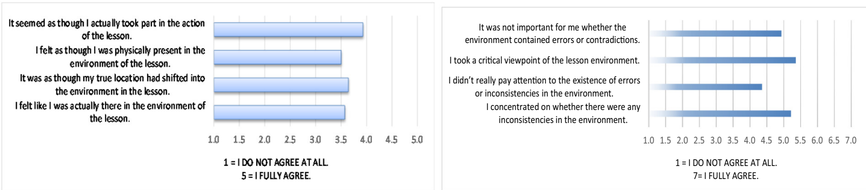

Fig. 3. (Left) sense of self-location in the immersive environment. (Right) perceived errors in the immersive environment

5.2 Technology Perceptions

We observed from the collected questionnaire that even though the learners enjoyed the immersive aspect of the technology (e.g., the feeling of 'being there') there are still several issues to address in terms of their self-location within the virtual environment. That is, for instance Fig. 3, Left, item Q4 "*I felt like I was actually there in the environment of the lesson*" had an average score of 3.6 from the respondents (Likert scale 1= not at all, 5 = completely). This indicates that the learners, perhaps, could not perceive themselves physically in the immersive environment as fully as they could perceive their teacher. Furthermore, due to the preliminary nature of the technology the environment tested was very basic, without distracting backgrounds or clues as to where the learners could be located inside of it. Also, Fig. 3, Right, item Q3 "*I didn't really pay attention to the existence of errors or inconsistencies in the environment",* had average score of 4.4 (Likert scale 1 = completely disagree, 7 = completely agree), indicating that in fact the learners did pay attention to glitches that occurred in the TIP environment.

Nevertheless, the focus group discussion revealed that the learners were comfortable enough with the technology, even at this stage, to accept it despite the limitations of self-location and errors that it presented, having strong feelings of 'being there', in the company of their teacher. During our testing, even though some of the learners had previous experiences of VR environments this novel immersive technology was totally new and different from anything else they had experienced before: the first time they could see someone else as her/himself in a virtual environment. A sample quote in the following from the focus group interview highlights the issue:

Interviewer: "*How did you feel when you went to the VR environment and you saw the teacher…*".
Girl1: "*Interesting, cool*".
Girl2*:* "*It was quite odd. I didn't expect to see him as a whole…*".
Boy1*:* "*It was kind of odd and interesting and exciting to see…*".
Boy2*:* "*It was kind of surprising, it was different than I expected.*"

These impressions of positive surprise and excitement also reveal a sense of novelty from the use of the technology, since all the students were experiencing a 3D immersive technology for the first time.

5.3 Educational Application Perceptions

The learners expressed in the focus group interview: "*It was quite odd, I didn't expect to see him as a whole, when you could see the teacher moving and all.*" (Boy2). "*It was kind of odd and interesting and exciting to see all expressions and the movements and all the little things.*" (Girl1) This indicates support for the learners to perceive each other in a more realistic way inside a virtual environment enabling observation of subtle details of objects e.g. for recognising people's faces and body language and (facial) expressions which can indicate the emotional state or level of comprehension of the others when communicating and working together.

In their answers, the learners also indicated they were able to communicate their intentions clearly to the teacher and that their thoughts were clear to the teacher, thus understanding each other meanings. The learners felt that the teacher paid close attention to them. Some of the learners mentioned they look curiously around the environment but that this did not actually disturb their concentration. They thought that when the novelty factor diminishes it would be even more like a normal learning environment for them. These reported experiences validate our H1, also offers a positive answer to RQ1.

6 Discussion

Based on results of preliminary experiments, we pose in Table 1 opportunities offered and further challenges to address use of immersive 3D video in educational contexts.

Table 1. Summary of challenges and opportunities offered by immersive 3D video

Perspective	Challenges	Opportunities
Sense of presence	HMD gadgets difficult usage. Lack of eye contact when using the headset Lack of eyes and face gestures when using the headset	Feeling of being inside the actual environment Feeling of being in the same space as the other and in his/her company Feeling of being able to understand the other's intentions and feelings
Technology	Need for technical assistance Laborious setup Cost of equipment HMD technology Environment background Technical glitches	Positive technology acceptance Technology attractiveness Support the learners to perceive each other in a more realistic way inside a virtual environment Recognising and observing people's faces and other objects in great detail High-fidelity body language and facial expression Ability to arbitrarily shift the focus of attention
Education	Dependence on adults, with pre-established power dynamics, which may result in a power imbalance Dependence on specialised technical skills	Learning and developing collaborative skills through online interaction Learning and developing digital skills for learners and teachers Learning to express and communicate ideas in an online environment Wide array of tools available for online and hybrid collaboration Non-obstructiveness enabling learners to focus on the learning process Shared interaction with real objects (e.g., using a real whiteboard, not a digital one) Unrestricted or informal positioning in the physical environment

Regarding a sense of presence, we observed from the collected questionnaire that even though learners enjoyed the immersive aspect of the technology there are still issues to address in terms of their self-location. The learners were comfortable enough with the technology, even at this stage, to accept it despite limitations of self-location that it presented, having strong feelings of 'being there', in the company of their teacher.

In terms of the technology implementation, the learners found the idea of being immersed in a 3D environment appealing, in spite of the issues reported with the use of an early prototype technology. Through the technology, the learners could perceive subtle body language and expressions that indicate the emotional state or level of their teacher's understanding of what the learner say. The technology also could offer the teacher the ability to direct their focus and look for cues on whether they and the task are being understood. A point of consideration, however, is the high costs of implementation of the technology at the present (about 30,000€ in this setup).

With regards to education, the technology could advance 21C skills in terms of collaborative online and hybrid learning. Furthermore, the technology is able to isolate or extract elements from the physical environment that could create distractions during interactive learning activities, or conversely it could augment the virtual environment with virtual elements. For online collaborative learning and connecting globally, beyond the classroom the technology could provide suitable solutions, since it can support the learners to perceive each other in a more realistic way inside a virtual environment enabling observation of subtle details of objects e.g. for recognising people's faces and body language and (facial) expressions which can indicate the emotional state or level of comprehension of the others when communicating and working together.

7 Conclusions

In this study, we investigated the experiences and sense of presence generated with a tele-immersive 3D video environment in K-12 education. We investigated what the main challenges are for the technology at the present as well as its potential positive effects. Based on the collected data, we were able to provide answers to our research questions regarding the preliminary investigation on the perceptions of the learners towards 3D telepresence technology for education and the impact the new medium currently has on the learners' sense of presence. According to our assumptions and first hypothesis, the perceptions of the learners on the use of immersive 3D video in education were positive. The learners expressed feelings of positive surprise and excitement and felt the technology enabled participation for them in the action of the lesson. Our second hypothesis was also confirmed, as immersive 3D video technology fostered a high sense of presence in the learners. The learners recounted the feeling that they were "there" inside the environment and in the company of the teacher being able to communicate their intentions and thoughts and to reciprocally understand the teacher.

Our study, however, presents limitations including the accessibility of the technology at present due to the high cost of the equipment, and persistent technical challenges, such as physical discomfort and software glitches that may hinder the system's use during regular curriculum instruction and education. Also, the number of participants was small, making it difficult to draw conclusions that are statistically relevant. Nevertheless, it is important to highlight the novel nature of our TIP technology under development. It would be useful to further investigate the effectiveness of instruction within an immersive 3D video environment in multiple iterations and lengthy implementations, in order to counter the novelty effect in the new technology, and increase the credibility of research findings, particularly under the participatory design paradigm. More research and development work are also needed to ease user access with lighter technical setups and enhanced portability to, for instance, mobile devices.

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DigiFit4All – Conceptualisation of a Platform to Generate Personalised Open Online Courses (POOCs)

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Abstract. The need for evaluated digital resources arose over the last years as blended learning applications became even more popular, and distance learning essential. Besides well-known *massive open online courses (MOOCs)*, approaches called *personalised open online courses (POOCs),* which present individual learning resources to the users, are developed. Personalisation is, in most cases, based on different information about the users. *DigiFit4All* is a project to develop a platform for POOCs, including open teaching and learning resources for lower and higher education. In the background, a competency model is used, which enables the definition of learning outcomes for courses, the determination of learning paths, and the assignment of learning resources. With the help of pre-tests, competencies that are already known can be identified. The learning resources are integrated into a *learning management system (LMS)* which imports them from open repositories. This contribution gives detailed information about the concepts of the *DigiFit4All* project and compares it to other approaches.

Keywords: POOC · e-learning · Digital learning resources · Competency models

1 Introduction

In our society, the relevance of digital teaching and learning is constantly increasing. Various forms of blended learning, e-learning or even distance learning are widespread, and partly necessary due to the current pandemic. A lot of material is available online in the form of massive open online courses (MOOCs). These platforms differ in several aspects concerning technological background and usability. The presentation of the learning resources is, in most cases, the same for all participants, and heterogeneity is not considered. Further, MOOCs often follow an asynchronous form and present their content in the form of videos, quizzes or reading tasks. Approaches that offer individually prepared courses and incorporate heterogeneity are called *personalised open online courses (POOCs).* They often base on learner profiles and an analysis of the results from prior assessments [1].

The project *DigiFit4All* started in May 2020 and has the aim to develop a platform for POOC creation. Based on competency models, which are stored as graphs, teachers

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can create their own courses and identify learning paths to reach the goals of the course. Students can attend individual courses by participating in pre-tests to determine competency profiles. In addition to the platform, resources for computer science and digital education topics are developed during the project. A cooperation between the University of Klagenfurt[1], the Danube University Krems[2], the Johannes Kepler University Linz[3], and the Vienna University of Technology[4] ensures that the different target groups of students in lower and higher education, teachers, and administrative staff can be covered.

This contribution summarises findings from the research literature (Sect. 2) that influenced design decisions during the conceptualisation of the *DigiFit4All* project, and different approaches are compared (Sect. 3). In Sect. 4, the components of the *DigiFit4All* system are explained in more detail, and the technological background is described. Section 5 presents an overview of the user roles in the project and sample workflows for teachers and students.

2 Related Work

To get a first overview of existing systems that can generate *personal open online courses*, several approaches that have been published already are reviewed, and the most relevant are briefly described below.

In 2007, Leung et al. [2] identified students' diversity as a significant issue in terms of e-learning. To answer how course materials can be presented student-centered, they suggested an approach following the elaboration theory of instruction combined with the so-called educational ontology.

El Mawas et al. [3] discussed the personalisation of massive open online courses in the context of lifelong learning. Their architecture consists of a *content management system (CMS)* and a *learning management system (LMS)* and supports different roles such as pedagogical engineer, teacher, and learner. Subjects, topics, and concepts are stored in *domain models*, while the individual results are saved in *learner models*.

Due to the low completion rates of MOOCs, Brinton et al. [4] developed the so-called MIICs. MIIC stands for *mobile integrated and individualised course* and is an *adaptive educational system* that updates students' user models based on their interaction with the course. MIICs offer multiple learning paths, whereby one path consists of several segments. One segment represents the 'smallest unit of knowledge' offered in different versions (depending on the path selected for the learner).

Another aspect in the context of MOOCs is big data. Compared to traditional classroom learning settings, online courses allow collection and analysis of learners' behavior as all actions performed by users can be logged. Xi et al. [5] described how the collected data could be interpreted using a behavior analysis model. They described

[1] https://www.aau.at.

[2] https://www.donau-uni.ac.at.

[3] https://www.jku.at.

[4] https://www.tuwien.at.

a model consisting of six components, whereby the *predictive model* is the centerpiece of it. Students can access the course content, and based on their interaction with it, the adaption engine updates their personal model. Teachers can intervene through the so-called intervention engine, which allows manual adjustments in the otherwise automatic system.

Analysing the related work showed that many ideas in personalising MOOCs had been made already. However, unfortunately, most of the introduced prototypes are no longer available, or the work on this subject was discontinued. However, some of the concepts that were described can or will be re-used in the *DigiFit4All* project in the presented or a similar way.

3 Components for POOCs

3.1 Used Components in Existing Projects

Analysing related work showed that the models described in the papers consist of several components, which will be identified and explained in this section.

A *pre-test* is used to determine the prior knowledge of a student before they start with the course. Based on their individual result during this evaluation, the course is adjusted to their personal needs. In the approach of Leung et al. [2], a pre-test has to be performed by the students, which sets the ground for the individual study path, while El Mawas et al. [3] ask the learner to fill a so-called positioning questionnaire as a basis for the learner model, created by the platform. Additionally, statements by the user are considered for the initiation of the model. The approaches suggested by Brinton et al. [4] and Xi et al. [5] do not contain any pre-test, and the learning paths are calculated later on.

A *post-test* is a test that has to be performed by a learner, and it is used to check the knowledge once a given activity, exercise or segment was finished. An automated mechanism that adjusts the learner model based on the users' behavior is not considered a post-test. The model of Leung et al. is the only one that lets their learners submit post-tests, while the other models use different approaches of measuring the performance.

Learning paths allow the individualisation of how someone learns. A person's path is adjusted to their personal needs, either depending on post-tests or calculations in the background. In the approach of El Mawas et al., the learning path is based on the positioning questionnaire and static, while the model of Leung et al. allows changes in the path depending on the pre- and post-tests. The platform by Xi et al. allows automatic as well as manual adjustments of the learning paths, and the approach of Brinton et al. considers the users' behavior in each segment to select the next one.

User behavior can be considered to create dynamic personalised courses, depending on how a learner interacts with the platform. As just described, Brinton et al. select the segment and version of the following learning object based on the results yielded in the current one. As the approach of El Mawas et al. is static, the user's behavior is not analysed during the course. The same applies to the model of Leung et al., as it depends on the tests performed by the user. Xi et al.'s platform uses behavioral data to recommend activities to the learner.

A *repository* is a platform where learning material that can be linked to learning objects is stored. Repositories can either be open platforms where everyone is able to provide course material that can even be used outside a course, or closed platforms that do not share their contents with the public. Three of the researched papers do not describe where and how the material is stored in detail; only Brinton et al. tell that all files are stored in EPUB containers, and videos are streamed via HTTP.

MOOCs are held in *learning management systems (LMS)* that offer a variety of features for course management. The analysed approaches used different platforms for the integration of their personalised courses: Leung et al. used Moodle, El Mawas et al. used edX, and both Brinton et al. and Xi et al. did not specify the platform or used a custom-created website.

Exams are defined as actual exams that are relevant for the grade of a learner in the subject of the course. None of the four analysed approaches supports writing an exam within the personalised course.

Learning objects can be used to modularise content for learning scenarios. They represent the teaching and learning materials and are defined following the *IEEE Standard for Learning Object Metadata (LOM)* [6]. Compared to segments in the approach of Brinton [4], learning objects collect 'smallest units of knowledge' to a didactically meaningful package. This concept appears only in the work of Leung [2].

A *microservice architecture* is a method to develop software based on small services with well-defined interfaces to easily add new services. In none of the analysed approaches a comparable architecture is described.

3.2 Comparison of the Approaches

The comparison of the approaches is based on the descriptions of the methods in the respective papers. In case any information was not found for a specific component, it is considered as not existent. As presented in Table 1, all components include learning paths for course personalisation. The pre-test approach is only used by two out of four models, and only Leung et al. included post-tests as well. None of the ideas presented used an open repository which allows uploading learning material. The components of the *DigiFit4All* approach together with the technical background will be described in the following section.

4 Components of the DigiFit4All Project

4.1 Overview of the Project

During the development process of the *DigiFit4All* project, literature was reviewed and approaches from related work were analysed. Existing expertise, previous work and research results of the partner institutions had the strongest influence on the project's basic idea.

Table 1. Component comparison of personalised online course systems

Component	Approach				
	Leung [2]	El Mawas [3]	Brinton [4]	Xi [5]	DF4A
Pre-test	Yes	Yes	No	No	Yes
Post-test	Yes	No	No	No	Yes
Learning paths	Yes	Yes	Yes	Yes	Yes
User behavior	No	No	Yes	Yes	No
Repository	No	No	Yes	No	Yes
LMS integration	Yes	Yes	No	No	Yes
Exams	No	No	No	No	Yes
Learning objects	Yes	No	No	No	Yes
Microservice architecture	No	No	No	No	Yes

Based on this prior knowledge, the following components were selected to be part of this project.

– Competency models: The background calculations for the personalisation are based on competency models and learning paths within the models.
– Learning objects: The teaching and learning materials to reach competencies are developed in the form of *learning objects*.
– Assessment: Course participants are assessed before a course starts, to get information about their knowledge and which competencies they already have acquired. After finishing a course, the learners are assessed again to find out which competencies they reached during the course.
– Learning management systems (LMS): The *learning objects* are presented in form of courses in chosen LMS.

These components work together to create personalised open online courses in the *DigiFit4All* project and are described in more detail in the following sections.

4.2 Competency Models and Learning Objects

As already mentioned, the personalisation of the courses in the *DigiFit4All* project is based on competency models. For this purpose, national and international curricula, educational standards, and competency models for different target groups are collected and analysed. As a central element, the learning outcomes of the models, here called *competencies*, are part of this process. In a first step, the competencies have to be standardised because some of them contain more than one outcome. This leads to *subcomptencies* which are *part of* competencies in their original form. The models are mapped to a graph-based representation form, and stored in a graph database as Pasterk and Bollin describe it [7, 8]. Competencies represent the nodes, and dependencies between them are displayed as directed edges. Pasterk defines the two dependency types *expands* and *requires*, which show that a competency *C1* is necessary to reach another competency *C2* within the same topic (*C2 expands C1*) or from another topic

(*C2 requires C1*) [9]. Nodes and edges are sometimes given by the curricula, educational standards, or competency models, but in many cases, the dependencies have to be added by experts. As the models are in general developed for one target group, i.e., primary school children or students of an undergraduate programme, Pasterk presents a method to combine them to one overall model, here called the *main index*. This approach uses so-called *intersector nodes*, which collect a set of similar competencies from different models in one single node. *Intersector nodes* inherit all dependencies from their included competencies, thereby connecting competency models to each other [9]. In the *DigiFit4All* project, the approach from Pasterk and Bollin is applied with some adaptations concerning the *intersector nodes*. Similar competencies are not collected in sets but are connected over an *equal to* relation. If a competency *A* is similar to another already existing competency *B* their respective nodes are set to be *equal to* another. In the main index only the node of the first competency B is shown and used for calculations. Again, the existing competency inherits all dependencies from competencies which are later added and set to be *equal to* it. For the purpose of collecting, analysing and combining the models, the *Graph-based Environment for Competency and Knowledge-Item Organization (GECKO)*[5] platform presented by Pasterk and Bollin in 2017 [7, 8] and described by Pasterk 2020 in detail [9] is adapted and extended by some functionalities.

In the graph-based representation, *central competencies* of the models and the *main index* can be identified and *learning paths* can be calculated. To find *central competencies*, the centrality values of the nodes are measures. This method is used in network analysis and adds information about important competencies [9]. *Learning paths* include competencies, which are necessary to reach a selected competency, by following the direction of the edges back to a selected starting node. Especially in the *main index* more than one learning path to a given competency can exist. In the *DigiFit4All* project, the *learning paths* support teachers, and lecturers to find necessary prerequisites for targeted competencies and to include them in their courses. Additional components, which are new in the *DigiFit4All* project, are *learning objects*. The mentioned LOM [6] standard includes different forms of materials, also non-digital ones, which are excluded from the *DigiFit4All* project. It is required that the materials are tagged with metadata to record information about them. Additionally, the *learning objects* are in subject to further project-specific requirements like a time limit and the highest possible degree of independence to other learning objects. These two requirements are important for the reuse of learning objects in different courses and contexts. *Learning objects* are developed to reach given competencies and are directly linked to corresponding competencies in the GECKO system.

4.3 Self-assessment for Personalisation

At the beginning and the end of a course, assessment questions are addressed to learners and serve to evaluate individual skills and competencies acquired before and after a course. The results of these pre-tests are used to determine the competencies that

[5] https://gecko.aau.at.

the learner would still have to reach to pass the course positively. These are then highlighted in the personalised online course, while topics that have already been mastered remain accessible, but are kept in the background. Items for the post-tests are used to check whether a competency has been achieved after finishing the course. They can be part of the exam and, with that, the grading. Both types of questioning, assessment questions and test items, are carried out via the *KAUA (Košice and Alpen-Adria University Assessment)*[6] platform of the Department of Informatics Didactics at the University of Klagenfurt. For the purposes of the *DigiFit4All* project, the platform is modified and extended. The idea behind the *KAUA* platform is to use hash values to identify users instead of storing specific user data [10].

4.4 Support for Learning Management Systems

To allow teachers to create courses for their students, integrations for *learning management systems (LMS)* are being created. Once the corresponding plugin for the LMS is installed, it will allow teachers to import courses for their classes. Students are then able to perform the pre-test and use their personalised course. As a first LMS, Moodle – which was already used by Leung et al. [2] in their implementation of personalised courses – will be supported as it is open-source, therefore available for free and open for further modifications.

4.5 Technical Background

The *DigiFit4All* system is designed as a microservice architecture. Most of the services are Spring Boot applications and therefore implemented in Java. During the project, two Single Page Applications (SPA) are also developed. Among other things, the application also provides an interface to an external repository and LMS. The repository in turn provides an interface to the LMS. Figure 1 below shows a section of this architecture. The API *Gateway Services* serves as the central access point to the backend. All stateless communication runs through this gateway, so the different microservices cannot be addressed directly. In Fig. 1, the most important services of *GECKO* and *KAUA* are visible. The *Auth Service* manages all users and authentication. The *Graph Service* manages the Neo4J graph database, which is used to map the various competency models. The *Liza Service* provides various recommendations when creating a competency model. This application is implemented in Python and communicates with the rest of the Spring-based application via the *Liza Service Sidecar*. The *Library* is not a standalone service but is added by each core service as a dependency. The *Survey Service* handles the creation of questions and questionnaires. The created questions can be added to surveys, competencies or learning objects. The survey data and the results of the tests for the personalisation of the different users are stored anonymously. Each time a user logs in, a hash value is generated from the user credentials in the *UID Service*. This hash value serves as an identifier for the user.

[6] https://kaua.aau.at.

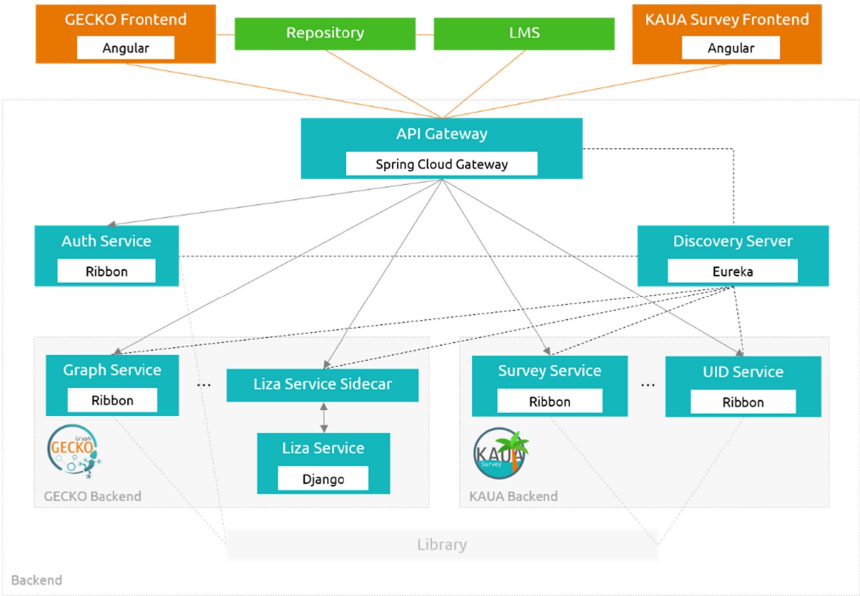

Fig. 1. Detail of the *DigiFit4All* system architecture

5 Roles and Workflows in the DigiFit4All Project

5.1 User Roles

Within the *DigiFit4All* project, different user roles exist for different functionalities in *GECKO* as well as in *KAUA*. In *GECKO*, users can register for free, but at this stage only have the possibility to view the *main index* as a list of competencies or in its graph representation. Every user can send a request to get the role of a *GECKO-author* or of a *GECKO-lecturer*. *GECKO-authors* are responsible for the competency models collected in *GECKO* and are able to upload or build their own models for their selected target group. The individual models have to be submitted and are evaluated by an expert team. In contrast to that, *GECKO-lecturers* use the given competencies in the *main index* to represent their goals for their own courses. This allows teachers or lecturers to follow the suggestions of the system, or to choose their own ways. Two of the three roles existing in *KAUA* work in a similar matter. *KAUA-authors* develop questions and question modules of different forms and for different purposes. The *KAUA-lecturers* combine given and evaluated modules to prepare their own surveys. The last role which does not require a typical registration is the *KAUA-student* role. An enrolled student can access their personal course through the LMS using their student data. After submitting the pre-test, students can start with the personalised online course. In the following section, the workflows for lecturers and learners within the project are described in more detail.

5.2 Sample Workflows

Workflow for Teachers. Based on the knowledge about the components of the project, the typical workflow for a teacher or lecturer starts with the assignment of competencies to a course in *GECKO*. They need to login to the platform with a corresponding account and define a new course, or work on an existing one. Starting to work on a new model, the first step is to select the target competencies from the *main index*. As an example, a teacher wants to introduce simple SQL statements in their databases course. For this category several competencies can be found but the following two are selected by the teacher:

1. Learners formulate SQL queries using a projection.
2. Learners formulate SQL queries with a selection.

These competencies are based on the *ACM/IEEE Computer Science Curriculum 2013*[7] but go more into detail. In the background, the system calculates necessary prerequisites for the target competency and suggests the results to the teacher. They receive a list of additional competencies including competencies from the topic's *relation schema* and *datatypes*. However, for the teacher, only competencies for SQL statements are of interest. That is why for the two selected target competencies, the following list of competencies is added to the course:

3. Learners can reproduce what is meant by a projection in SQL queries.
4. Learners understand and can explain what is meant by a projection in SQL queries.
5. Learners can reproduce what is meant by a selection in SQL queries.
6. Learners understand and can explain what is meant by a selection in SQL queries.

Competencies 3 and 4 are prerequisites for (1), and 5 and 6 for (2), as they deal with the same topics on different cognitive levels. The teacher decides whether as foreknowledge suggested competencies should be added to the course or not (step 2). In the given example, the teacher also adds the prerequisites to the course. After the competencies are selected, the teacher gets a list of teaching and learning materials that can be used to reach the corresponding competencies (step 3). Again, the teacher selects those materials that are appropriate for the course (step 4). This step includes the option to create a final exam with questions related to selected competencies and marked to be exam questions. For the competencies in the database-example, the teacher chooses interactive videos to be appropriate for the course, but chooses not to have a final exam through the system. These steps are illustrated in Fig. 2 and show the actions taken in the *GECKO* platform. Additionally, a teacher can create own surveys and tests in *KAUA*. Again, existing modules for different purposes can be chosen from the existing collection, or own questions can be defined. Once the teacher enabled the connection to *GECKO*, the course created can be selected by its title. The learning objects corresponding to the selected competencies are imported from the repository into the LMS section.

[7] https://www.acm.org/binaries/content/assets/education/cs2013_web_final.pdf.

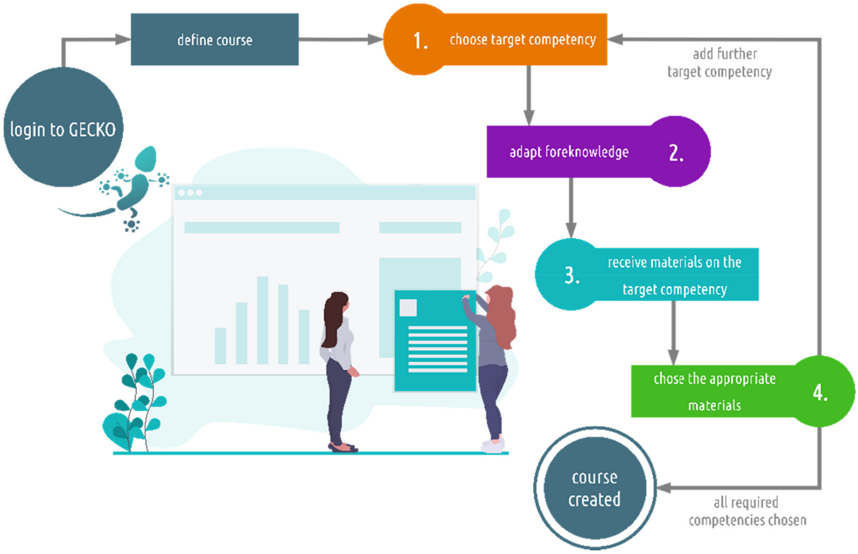

Fig. 2. The workflow for teachers and lecturers in the *DigiFit4All* project

Workflow for Learners. As mentioned above, the students do not register to the system on their own. In higher education, a student enrolls for a course in the affiliated institution's usual system. Through the student account, they get access to the used LMS and with it to the learning resources. For students in schools, the administrator or the teacher must generate a list of student accounts in the LMS system of the school. With that account, the students can enter the online course. From this point on, the workflow for all kind of students is the same. The first step is the pre-test. Depending on the LMS, the students can participate directly in the LMS or have to follow a given link to *KAUA*. Based on the results of the pre-test, a competency profile of each student is created and stored. Looking at the example for a database course with competencies in SQL statements, a section of the pre-test would include self-assessment questions in the following form and for the corresponding competencies (see the referencing numbers in the brackets):

- Have you heard about projections in the context of databases and SQL statements? (Competency 3)
- Can you explain a projection in the context of databases and SQL statements? (Competency 4)
- Have you created an own SQL query including a projection? (Competency 1)
- Have you heard about selections in the context of databases and SQL statements? (Competency 5)
- Can you explain a selection in the context of databases and SQL statements? (Competency 6)
- Have you created an own SQL query including a selection? (Competency 2)

As a next step, the student has access to the learning material of the online course. With the help of the competency profile, the course is personalised for each student. This means, the sections for already reached competencies are put into the background and the other sections are highlighted. Through this approach, the student identifies on the first glance which sections are important for them. However, they still have access to all learning resources, as they are relevant for the exam.

So, for the given example it can be assumed that a student has already read something about SQL statements and knows the difference between projection and selection, but has never created an own query. This student only replies with ‘No’ to the questions for competencies 1 and 2. With this profile, the course for this student includes four collapsible sections which contain the interactive videos for competencies 3 to 6. Two already opened sections present the two videos for competencies 1 and 2, which are not yet reached by the student. After a student has worked through all the materials, they participate in a post-test. This test depends on the selected competencies for the course and not on the profiles of the students. Therefore, even questions about topics, which the student already knew about before participating in the course, can be included. Results from the pre-test have no influence on the post-test.

In case of the given example about SQL statements, post-test questions can include the following questions or tasks:

- What is a projection in the context of databases?
- What is necessary to create a simple SQL query?
- What is the result of a given query over a given table?
- Create a query to get given results from a given table.

It has to be mentioned that the post-test is not the same as an exam, which has to be passed to receive a grade for the course. The post-test informally shows the progress of participating students, but does not influence the grades.

6 Conclusion

This paper presents an analysis of existing approaches for *personalised open online courses (POOC)* and discusses differences and similarities. Research in related work shows that several prototypes were created. However, most of them are no longer available as they only served as proof of concepts or were discontinued for other reasons. Several components used in the mentioned approaches could be identified and compared to each other as well as to the *DigiFit4All* project. The results show that all selected approaches use *learning paths* in the background. Three of five approaches include *pre-tests* and some kind of *LMS integration*. Considering other points like *post-tests*, *exams* or *user behavior,* the approaches differ more. A detailed description of the structure of the *DigiFit4All* project includes the use of *competency models* in the background to create courses and calculate *learning paths*, the development of independent and reusable *learning objects*, the necessity of assessment before and after the course, *learning management systems* support as well as the technical background. By explaining the roles and two sample workflows, it is shown what users (both learners and lecturers) can do on the *DigiFit4All* platform. The project started one year ago, and a first prototype of the *GECKO* platform is already online, including some first competency models. In a next step, a repository will be created and linking learning objects to competencies will be supported, as well as the import into learning management systems.

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Management Issues

What Kind of E-assessment Feedback Is Important to Students? An Empirical Study

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Abstract. E-assessment needs to provide detailed feedback that students would use. To this end, the content of feedback should include assessment information that is important to students. By using a convenient sample of twenty second-year undergraduate students, this study explored the extent to which different kinds of assessment feedback were important to students. Therefore, an online questionnaire was administered which, apart from asking values of some background variables including academic achievement, listed a number of different feedback techniques supporting activities applied in deep and strategic approaches to learning and studying. For each technique, students had to indicate the extent of the importance they assigned to it. It was found that: (1) although feedback techniques supporting a deep approach were as important to students as those supporting a strategic approach, the importance of the former was positively related to that of the latter; (2) feedback techniques supporting a deep approach were more important to females than males; (3) when the importance of all these feedback techniques together was considered in a specific way, their relevance to an increase in students' knowledge, skills and motivation could be demonstrated. Although this study used a small sample that might characterise it as preliminary research, it revealed valuable findings, which due to their considerable effect size, make the sample size less questionable. Suggestions for further research are included.

Keywords: E-assessment · Feedback · Language learning · Learning approach · Undergraduate students

1 Introduction

Feedback has one of the highest effects on learning (e.g. [1]). Concerning e-learning, research has identified some kinds of feedback that may be important to instructors (e.g. [2]). Less is known about the kinds of feedback that may be important to students (e.g. [3]), especially about those related to e-assessment. These kinds of feedback should be personalised [4] and have content that engages students in self-regulated learning [5]. Furthermore, students should have some control over learning analytics (e.g. what can

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be seen by them, what by other students), respecting their preferences for automated alerts over those sent by teaching staff [3].

As a critical component of education, assessment can be used to improve both learning and instruction (e.g. [6, 7]). In the context of e-learning one may first focus on e-assessment feedback and later on other feedback types sent by teaching staff, which, as mentioned above, may be less preferred than feedback automatically sent by the assessment system. To improve e-learning, among other things, assessment needs to provide detailed feedback that students would actually use [8]. Accordingly, the content of feedback should include assessment information important to students (e.g. [3]). Such information may support students' activities applied in their approaches to learning and studying [9].

The concept of an approach to learning, introduced about forty years ago, made a distinction between a deep approach and a surface approach. While the former aims at understanding the material learned, relating it to previous knowledge and experience and examining evidence supporting conclusions, the latter aims at satisfying requirements of a task or a course through memorising details that would be most likely assessed. The strategic approach was added later to denote a combination of deep and surface approaches applied in order to maximise achievement [10]. The so-called SAL (Student Approaches to Learning) perspective has been mainly concerned with students' behavior that can be described using their self-reports or the questionnaires they complete [11].

Subsequent research has clarified the main features of these three categories. These features may be summarised in the following way: "deep (intention to understand, relating ideas, use of evidence, and active learning); surface (intention to reproduce, unrelated memorising, passive learning, and fear of failure); strategic (study organisation, time management, alertness to assessment demands, and intention to excel)" ([12], p. 433). Note that while deep and surface approaches are approaches to learning, the strategic approach, which combines them, may be considered more as an approach to studying than as an approach to learning [13].

Having in mind the features of the approaches summarised above, to facilitate genuine learning based upon understanding, assessment feedback may support the deep approach. This feedback may also support a strategic approach because it involves a deep approach to some extent (e.g., a good study organisation may contribute to relating ideas).

Are deep and strategic approaches related to achievement? Research suggests that there may be a positive relationship between academic achievement and a strategic approach, whereas this achievement might be unrelated to a deep approach (e.g., [12]).

To contribute to under-represented research on kinds of assessment feedback that may be important to students, this study asked its participants to assign importance to different feedback techniques supporting activities applied in deep and strategic approaches to learning and studying. Hence, they completed an online questionnaire that also collected their basic background data including academic achievement.

The study examined the following research questions:

1. Which feedback techniques were more important to students: those supporting a deep or a strategic approach?

2. Considering each approach, were there any relationships between the importance of feedback techniques supporting it and background variables used?

These questions were answered by a sample of second-year undergraduate students who studied information technologies at a private faculty.

2 Method

2.1 Sample

This study used a convenience sample comprising twenty second-year undergraduate students who studied software engineering, information technologies, information systems, and game development at the Faculty of information technologies. Students enrolled in an English course – "English for IT" were invited to participate in the online survey administered. Of those who completed this course and passed the final exam, about 40% also completed the survey, which is a good response rate, bearing in mind that the average response rate for online surveys is around 30% (e.g., [14]).

The participants' background data were the following: five students were females; eleven students completed almost all tests; course achievement of ten students was 9 or 10, i.e. they received the highest marks (a 6–10 scale was used with 6 denoting the lowest passing mark); average academic achievement (considering all courses completed) was between 8 and 10 for ten students.

2.2 English Course

Course Content. "English for IT" is an LSP (Language for Specific Purposes) course held in the fall semester in Year 2 following two General English courses in Year 1. It is an upper intermediate course at level B2+ (Strong Vantage), with some elements at level C1, but it is more demanding than the previous two courses regarding the use of specialist language. It combines General English and English for specific purposes (Information technology). The course objective is to consolidate grammar use at upper intermediate level, expand general, and particularly professional vocabulary, as well as practice its use in various language functions. The course helps students to improve and integrate all language skills: speaking, listening, reading, writing, and translation.

This course comprised 15 units regarding IT topics to be covered in 15 weeks of academic work. Each unit focused on different vocabulary, linguistic, and grammatical content. For example, Unit 4 "Networks" focused on vocabulary about computer networks and relative clauses as far as grammar is concerned. Although the content of these units might be considered unconnected at first sight, there was some overlapping content. For example, Unit 2 "ICT in Education" focused on present tenses which appeared later on throughout the course; Unit 3 "The History of ICT" revised all past tenses without which it was also impossible to deal with later grammatical areas (conditionals, etc.).

The syllabus of this course and all learning materials, including tests, were developed by the second author of this study, who taught most students engaged in the course. The remaining students at another faculty site were taught by a different teacher who followed the approach developed.

E-tests and Feedback Provided. In order to get points for effort as a pre-final exam activity, students had to complete successfully two progress tests in every unit, thirty tests in total. There were two test restrictions to choose from: Time limit and Assessment passing mark. The former was not taken into consideration in this study while the latter was set to 5 questions: each test comprised six questions to answer, and the test was passed if correct answers were given to at least five questions. If the student failed the test, he/she could take another test with similar content.

There were three types of questions in the tests: multiple choice, fill-in-the-blank/short-answer (one word only), and true or false; for example:

> Choose the correct idiom to complete the following sentence: In today's world, computers are ____________ of daily life.
> a) part and parcel
> b) first and foremost
> c) belt and braces

There were 30 questions prepared in the question base for each test to be included in a 6-question test randomly: 900 questions in total for the whole course. All the questions were meticulously created in order to check if the students had understood the lesson they had just read and interacted with. Each lesson consisted of six learning objects[1]. While Test 1 was given after presentation of the third learning object, Test 2 was given at the end of the lesson.

The tests included limited feedback to students. Some of the possibilities in the test settings allowed by the e-learning environment were the following:

- Display all questions and answers once the learner finishes;
- Allow learners to see question feedback after each question;
- Indicate choices that have been answered correctly;
- Indicate choices that have been answered incorrectly;
- Allow learners to see history of responses at the end of each attempt;
- Display overall feedback at the end of each attempt;
- Allow learners to see grades at the end of each attempt.

In this course, the e-learning system only displayed the number of correctly answered questions, and for each question, information on whether the given answer was true or false, i.e. the learners were allowed to see grades at the end of each attempt. For example, when a student answered correctly three out of 6 question, he/she got the following feedback:

[1] A learning object is a specifically designed, modular unit of a learning resource – content items, practice items, and assessment items that are combined based on a single learning objective.

Sorry, you haven't scored 5 required to pass the activity. Please, try one more time. Grade: 3 out of a maximum of 6 (50%)

This was followed by a list of questions just ticked or crossed. Although different types of automatic feedback were available, the faculty executives decided to use standard summary responses to correct and incorrect answers, as well as the test score. Additional feedback received by students during the course includes the teacher's comments about the outcomes of project work and its presentation, as well as of individual and group practice including and combining various language issues (vocabulary, grammar, pragmatics).

This study aimed to collect students' responses about feedback techniques that were important to them to have solid grounds to improve the system in months to come and to provide feedback that would be more valuable to students.

2.3 Design and Variables

This study mainly used a factorial design and a correlative design. There were four background variables: *Gender* (with values: 1-male, 2-female); *Course achievement* (1-grade 9 or 10 was received, 0-otherwise); *Academic achievement* (1-average achievement for the courses completed was between grades 8 and 10; 0-otherwise); and *E-assessment participation* (1-almost all tests were completed, 0-otherwise).

The main variables were: *Deep approach feedback techniques importance – DAFTs importance* (average value of the importance of five feedback techniques supporting a deep approach, expressed on a 0–10 scale for each technique); and *Strategic approach feedback techniques importance – SAFTs importance* (average value of the importance of five feedback techniques supporting a strategic approach, expressed on a 0–10 scale for each technique).

2.4 Instrument and Procedure

The values of the variables used in this study were collected through an online survey using a questionnaire available on the Internet. Table 1 lists items (indicators) used to measure the two importance variables. *DAFTs importance* was measured using items D1–D5, whereas *SAFTs importance* was measured using items S1–S5. These items were listed in the questionnaire in the following order: D0, S1, D1, S2, D2, S3, D3, S4, D4, S5, D5, S0; D0 and S0 denote discarded items. Although there is no clear-cut solution to ordering items, there may be a certain advantage of intermixing them when different but related constructs are measured within a particular context [15].

The students involved in the English course were invited to participate in the survey by the second author of this study via e-mail. The survey was conducted in March 2021.

2.5 Data Transformation and Statistical Analyses

To attain a more reliable measurement of DAFTs and SAFTs importance, the raw data regarding the indicators of each importance variable were transformed into Guttman's [16] image scores (e.g. [17]). (It should be noted that the means and medians of the transformed data are slightly different from those of the raw data).

Table 1. Indicators of the two importance variables

Variable/activities to support [12]	Indicators
DAFTs importance/intention to understand, relating ideas, use of evidence, and active learning	**D1** Information is obtained about areas that I have successfully mastered in the current knowledge test versus areas that require additional learning **D2** A link is given to a file whose content shows how certain questions from the test are related to the content which needed to be learned **D3** A link is given to a file whose content indicates which test contents are related to other contents that are studied in the course **D4** A link is provided to a file whose content indicates how knowledge and skills that are the subject of the test can be implemented from different point of view **D5** Information is obtained about which areas in the current knowledge test I could receive special learning assistance for, from the professor
SAFTs importance/study organisation, time management, alertness to assessment demands, and intention to excel	**S1** A link is provided to a reminder with the most important facts about the knowledge and skills assessed by the test **S2** Information is obtained about how successful I was in solving the tasks in relation to the success of other students who had already solved the test **S3** Information is given about my individual results and the average result on completion of the knowledge tests **S4** A link is given to a file that, according to the order of presentation, locates the part of the course (lesson) that is the subject of the test in relation to other parts that appeared or will appear in other tests **S5** Information is obtained about the order in which individual knowledge and skills will be assessed at tests that should be completed during the semester

This resulted in a considerably improved reliability of both importance variables: from 0.732 to 0.936 for DAFTs importance and from 0.730 to 0.942 for SAFTs importance.

Apart from determining medians of the two importance variables, this study made use of two statistical tests. Wilcoxon signed-ranks test for dependent samples was applied to answer research question 1, whereas Wilcoxon rank-sum test for independent samples were carried out to answer research question 2. These nonparametric tests were used because no assumption needs to be made about the shape of the population distribution of variable in question, which is appropriate when small samples are used and the assumption of normality is violated for some variables (e.g., [18]).

To find out effect size, Cohen's r was calculated. As usually assumed, 0.5 evidences a large effect, 0.3 a medium effect, and 0.1 a small effect (e.g., [19]).

A correlative analysis concerning the applied variables was used to signal the relationships among them, if any. To this end, Spearman's correlation coefficients were determined. Note that for dichotomous (binary) variables, these coefficients are equal to those of Kendall or Pearson.

3 Results

The medians of the two importance variables were 7.43 for feedback techniques supporting a deep approach and 7.54 for feedback techniques supporting a strategic approach. These values were not different statistically (z = –0.747, p = 0.469).

Correlations among the six variables applied and their significances are given in Table 2. Considering relationships between the importance variables and four background variables applied, only one relationship was found (0.571, df = 18, p = 0.009). This positive relationship evidenced that feedback techniques supporting activities applied in the deep approach were more important to females than males (W = 129.0, z = –2.489, p = 0.010; Cohen's r = 0.56 – a large effect).

Table 2. Spearman's correlations among the six variables applied

Variable	Correlations				
	2	3	4	5	6
1. DAFTs importance	0.825**	0.571**	0.000	0.121	−0.044
2. SAFTs importance		0.351	−0.069	0.052	0.009
3. Gender			−0.115	0.346	0.058
4. Course achievement				0.600**	0.503*
5. Academic achievement					0.503*
6. E-assessment participation					

*p < 0.05 **p < 0.01

As DAFTs and SAFTs importance were almost unrelated to the four background variables applied, these importance variables were then jointly considered using a new importance variable named *Golden middle feedback techniques importance – GMFTs importance* with values: 1–both DAFTs and SAFTs importance values were between the 25th and 75th percentiles of their values; 0–otherwise. Two significant relationships emerged: between GMFTs importance and Course achievement (0.612, $df = 18$, $p = 0.004$) and between GMFTs importance and E-assessment participation (0.533, $df = 18$, $p = 0.015$). These positive relationships evidenced that participants indicating a golden middle importance not only had a higher course achievement ($\chi 2 = 7.500$, $df = 1$, $p = 0.006$) but also participated in e-assessment more often ($\chi 2 = 5.690$, $df = 1$, $p = 0.017$).[2]

4 Discussion

The first research question asked which feedback techniques would be more important to students: those supporting a deep or a strategic approach. It was found that both sets of techniques were equally important to students, who assigned high importance to them (both medians were above 7 on a 0–10 scale). Correlation between these was also high (Spearman's rho was 0.83, $df = 18$, $p = 0.000$; 95% CI: [0.54, 0.94] – an analytic estimate versus [0.62, 0.92] – a bootstrap estimate [20]). This outcome suggests that these two sets of feedback techniques were viewed beneficial to each other as deep and strategic approaches might contribute to each other positively; measures of these approaches may positively correlate in general (e.g., [21]). This line of reasoning may be used to explain the equal importance found because the participants' responses to adjacent item-pairs (S1, D1; S2, D2; S3, D3; S4, D4; S5, D5) were not similar to one another.[3] Another possibility is that the issues in question differ for different sub-groups of students (canceling each other), which was not found in this study.

As underlined in the Introduction, knowledge about feedback that may be important to students is scarce, especially related to e-assessment. However, this feedback should be personalised [4] and have content that engages students in self-regulated learning [5]. Furthermore, students should have some control over learning analytics (what can be seen by them, what by other students; whether information is communicated by the e-learning system automatically or by teaching staff), respecting their preferences for automated alerts over those sent by teaching staff [3]. Bearing in mind these feedback requirements, learning could be improved by applying learning/studying-approaches-based feedback techniques which students find important. In doing that, students' preferences for automated alerts over those sent be teaching staff may hold true in general, as found in this study for feedback technique D5 – "Information is obtained for which areas in the current knowledge test I could receive special learning assistance

[2] GMFTs importance and Gender correlated (−0.471, $df = 18$, $p = 0.036$). Relevant partial correlations concerning GMFTs importance controlling for Gender were: 0.637, $df = 17$, $p = 0.003$ (with Course achievement); 0.444, $df = 17$, $p = 0.057$ (with Academic achievement); 0.637, $df = 17$, $p = 0.003$ (with E-assessment participation).

[3] The mean of absolute difference between the responses to these item-pairs was calculated for each participant (e.g., [15]), and the mean and standard deviation of this measure were 1.86 and 1.37, respectively. Furthermore, the measure positively correlated with Course achievement (0.574, $df = 18$, $p = 0.008$), meaning that participants with lower course achievement responded to adjacent item-pairs in a more similar way [22].

from the professor" compared to the remaining feedback techniques of not only the deep approach but also both approaches.[4]

The second research question sought to uncover relationships, if any, between the importance of feedback techniques supporting a particular approach and background variables considered. It was only found that feedback techniques supporting a deep approach were more important to females than males. Although gender differences in language learning have not followed consistent patterns, several studies have evidenced that females may be better learners than males due to their higher language proficiency, stronger vocabulary knowledge, and better use of learning strategies (e.g., [24, 25]). To attain and maintain such a status, females may in general more often apply a deep rather than a strategic approach. They thus might, compared to males, assign more importance to feedback techniques supporting a deep rather than a strategic approach.

As mentioned in the Introduction, there may be a positive relationship between academic achievement and a strategic approach, whereas this achievement might be unrelated to a deep approach (e.g., [12]). Because of that, it was expected that feedback techniques supporting a strategic approach might be more important to students who had better achievements, but this importance was not related to any achievement variable ($W \geq 98.5$, $|z| \leq 0.492$, $p \geq 0.643$). However, significant relationships in question were found when DAFTs and SAFTs results were combined using variable GMFTs importance mentioned above: there were positive relationships between GMFTs importance on one side and Course achievement and E-assessment participation on the other. These findings provide some evidence that, where considered together in a specific way, DAFTs and SAFTs importance could explain an increase in students' knowledge, skills and motivation. The findings also suggest that instead of focusing on individual relationships between the importance of particular feedback techniques and relevant learning variables, researchers may relate these variables by combining different kinds of feedback techniques.

The previous paragraphs present some educational benefits of the feedback techniques examined. Apart from discussing these benefits, the cost of producing this feedback may also be examined. As the production of quality feedback has a high development time cost (e.g., [26]), the implementation of feedback examined in this study may at first sight appear as a costly enterprise. Typical automated response in a learning management system (e.g., "Correct" or "Incorrect! The answer is bridge!") may be extended in the direction of feedback techniques D1 and S1 (e.g., D1 – "Please go back to Sect. 3 Vocabulary Building to consolidate basic terminology on Networks"; S1 – "Please refer to our mind map with the basic terminology about Networks"), but this extension requires that each question entity is coupled with different feedback techniques, which may not be supported by the assessment system at hand. Because our feedback techniques need to be connected to various assessment entities at different levels (whole course – S5; lesson – D4, D5, S1, S4; learning object – D1;

[4] The medians of D5 importance, DAFTs4 importance (the remaining four DAFTs), FTs9 importance (the remaining nine FTs) were 6.66, 7.58, and 7.42, respectively. Their differences in question were significant: D5 importance – DAFTs4 importance: $z = -3.286$, $p = 0.000$; D5 importance – FTs9 importance: $z = -2.688$, $p = 0.005$. D5 importance was of high reliability by applying correction for attenuation (e.g., [23]).

question – D2), an appropriate form-based editor supporting a field hierarchy needs to be previously implemented at the assessment system. When this editor is available, which increases (possibly not much) the overall production cost, the test developer task would only require modest extra work beyond the typical [27].

Due to different experience with tests, feedback techniques that were important to students who completed almost all tests might differ from those important to students who completed these tests (much) less often or not at all. Because such differences were not found for two importance variables as well as their individual items ($W \geq 70.5$, $|z| \leq 1.846$, $p \geq 0.073$ for all these indicators), it was possible to consider all students as being members of one homogeneous group.[5]

To summarise: this study used a small sample that might characterise it as preliminary research, especially when gender differences were considered (there were only five females). Despite these limitations, the study revealed valuable findings, which due to their considerable effect size, make the sample size less questionable. These findings may be re-examined in future research using larger samples and a number of background variables. Such elaboration may reveal additional differences among students from different sub-groups. Knowing these differences can support the implementation of e-learning feedback that is more relevant to students, which would hopefully improve their learning outcomes.

5 Conclusion

This study aimed to enhance our knowledge about the feedback techniques that are important to students. Focusing on deep and strategic approaches to learning and studying, this study explored students' opinions about the importance of feedback techniques supporting these approaches and searched for student characteristics that might relate to that importance. It was found that feedback techniques supporting a deep approach were as important to students as feedback techniques supporting a strategic approach. Furthermore, feedback techniques supporting a deep approach were more important to females than to males. Finally, when the importance of these feedback techniques were considered together, their relevance to increase in students' knowledge, skills and motivation could be demonstrated. This survey was conducted for English courses. Further research may examine whether similar conclusions might apply for other courses in different subject areas.

Despite some ambiguity regarding the notion of a learning approach (e.g., [28] often considered as a learning style), this notion can be used to define e-assessment (e-learning) feedback techniques through associating them with key features of particular learning approaches, especially those that contribute to genuine learning (e.g., [9]). Although this study did not consider students' learning approaches, further research may do so through connecting feedback techniques endorsed by students with learning approaches they apply. With such connection at hand, e-learning systems may adapt

[5] As expected, E-assessment participation was positively related to achievement (see Table 2; $\chi2 = 5.051$, $df = 1$, $p = 0.025$ for both achievement variables).

not only learning content and sequence (path) to student's learning approach (e.g., [29, 30]), but also learning feedback to that approach (done automatically or with respect to students' preferences), aiming at, whenever possible, facilitating self-regulated learning with understanding.

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Shifting to a Technology-Driven Work Mode: Workplace Learning and Dynamic Capability in the Case of a Public-Sector Service Organisation

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Abstract. Learning to operate in technology-driven working modes is topical in many organisations today due to the COVID-19 pandemic crisis. The pandemic has forced especially knowledge-work organisations to quickly shift to remote or hybrid working modes, where all or some of the staff are operating and collaborating via digital tools. The aim of this qualitative case study is to explore and explicate a learning story of an organisation within the public sector transitioning quickly to a technology-driven hybrid working mode during the crisis. As findings, the paper presents the identified immediate and evolving facilitators that point to the organisation's learning to develop capabilities for operating effectively in the enforced and volatile conditions. Additionally, the potential long-term organisational development effects stemming from the situation are considered. In the findings, social aspects of work, such as open communication, collaboration, and awareness gained emphasis, while digital technology is one of the ground enablers. We apply a frame of dynamic capabilities together with workplace learning and aim to provide new insights into their development processes with a cross-organisational approach. In terms of practical implications, we suggest new understandings for the management on how organisations may learn and fare under uncertainty, volatility, and transitioning to digital collaboration.

Keywords: Dynamic capabilities · Workplace learning · Remote working · Hybrid · Facilitators · Qualitative · Case study

1 Introduction

The COVID-19 pandemic has had significant effects around the globe since the turn of the year 2019–2020. From an organisational perspective, it has forced many organisations to suddenly move to a vast remote working mode, and, consequently, to "technology-driven" [1, p. 1] collaboration enabled by digital technologies. [1–3] To successfully manage in the new working conditions, organisations need to learn, and they need to learn fast. Topical research on the effects on workplaces and organisations has already been conducted (e.g. [2, 4, 5]). However, more understanding of organisational learning mechanisms is required, both as the current crisis unfolds and as digitally enabled operating modes keep transforming work in different ways [3, 6, 7].

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In addressing this need, we identify a confluence of two research streams. First, dynamic capabilities research relates to organisational agility and the capability to quickly adapt to changing conditions in operational environments. The conditions may include changing markets, competition, disruptive technologies, and other factors that make organisations' environments turbulent. [7–9] Second, the workplace learning perspective and particularly learning organisations appear relevant in the contexts of increasing technology use in working life and the changing contents of work [10, p. 131]. This motivation appears yet more topical in the current conditions and future anticipated digitalisation of work [6].

Against this background, we apply dynamic capability [9, 11] and workplace learning [6, 10] as lenses for studying organisational learning and capability development in suddenly changing conditions, where digital technologies play a key role in effective operation [1]. We ask, *what facilitates organisational learning for developing the capability to operate effectively in an enforced technology-driven work mode during a volatile situation?* In addressing the question, the paper covers a qualitative case study [12] exploring organisational learning and capability development in the case company, which operates within the public sector in the Nordic region. The data were collected by twelve semi-structured interviews [12] conducted during the pandemic restrictions with professionals from the case company. The interview material was analysed by a combination of abductive [13] and inductive approaches [14].

As findings, we present a set of organisational phenomena, which we suggest facilitate learning and capability development in the case organisation. The facilitators encompass *organisational response and managerial action*; *staff readiness and commitment*; *multi-functional, continuous collaboration*; *increased awareness*; *learning new practices*; and *anticipated long-term organisational development*. The facilitators appear to progress temporally [3] from immediate and evolving to longer-term development, as the pandemic situation and the new working mode become familiar. The findings point towards inter-related cycles of dynamic capabilities of sensing, learning, integrating, and coordinating [9] manifesting across the organisation [11] as the facilitators evolve. Finally, social aspects of work [6], such as open communication, collaboration, and awareness (cf. [10]), gained emphasis in the findings, while digital technology is one of the ground enablers.

This paper aims to contribute to the understanding of organisational learning and capability development in an interdisciplinary manner [10] in the context of a suddenly enforced technology-driven work mode [1, 2]. We primarily build on information systems (IS) and management literature while reaching to the related field of workplace learning. Next, the background and theoretical underpinnings are discussed in Sect. 2, followed by the case description and methodology in Sect. 3. The qualitative findings are presented with examples in Sect. 4. The theoretical and practical discussion is carried out in Sect. 5, and the limitations, suggestions for further research, and concluding remarks are found in Sect. 6.

2 Background and Theoretical Underpinnings

The COVID-19 pandemic started to shake the world at the end of 2019 and reached Northern Europe in early 2020. In the wake of the pandemic, virtually all organisations capable of conducting their tasks in a remote working mode were suddenly forced to do so, which transformed collaboration from an on-site, face-to-face mode to a largely virtual one [1, 2]. Recent research has uncovered many effects of the situation on working and organisations, such as technology issues in different industries [5], changes in the means and affordances of knowledge-work teams' collaborations [2], the impact of the situation on IS management [4], and assessments of adopting new practices in organisations [1].

Two notable aspects emerge from the literature. First, managing in the situation seems not only to be about the technology itself (cf. [6]). Remote working practices appear to play an important role in organisations' success in these circumstances [1, 2, 5]. As the means and affordances of collaboration shift from an office environment to a home environment, both positive and negative effects on collaboration have been seen. Technologies enable continued collaboration to meet business goals, but they also introduce challenges to traditional ways of collaboration [2]. Second, time seems to be a central variable [3]. It becomes a scarce resource and organisations are under time pressure when moving to the new technology-driven ways of working [1]. The faster an organisation managed to operate as business-as-usual, the sooner it was found to recover to normal operations [4], which highlights the importance of organisational agility [7, 15].

While organisations aim to sustain their business as usual under the new circumstances (cf. [2, 4]), quick adaptation and learning on many levels are required. On the one hand, many organisations had no existing strategies, practices, or infrastructures in place to accommodate such a sudden, large-scale shift. On the other hand, not all individuals and teams were used to operating in a virtual mode [1, 2]. The situation underscores the necessity of quick, "continuous learning" in the workplace [10, p. 131]. In developing "digital workplaces," technologies and systems, and their use, have gained importance, while an understanding of work practices, creating a common goal, and a view of the whole have been found necessary from a learning perspective [6, p. 11–12]. Learning as an organisation revolves around the organisation's and its members' capacity for change and increased effectiveness. Open communication, empowerment, and collaborative culture are identified as requirements. In the context of this study, we identify learning in the workplace as an informal, emerging, and participative process of creating and learning new modes of operation, practices, and knowledge at the organisational level. [10]

Next, dynamic capabilities [9, 11] are identified as fitting lenses to explore learning and capability development in a turbulent, digital technology-intensive environment [7] where organisations operate under time pressure [1]. Dynamic capabilities have been defined in several ways [16]. A high-level core definition names three main organisational capacities, sensing opportunities and threats in the environment, seising the identified opportunities, and continually renewing, or transforming, the organisation [8]. In this paper, we utilise a somewhat more detailed model including *sensing*, as "the ability to spot, interpret, and pursue opportunities in the environment," *learning* "to revamp existing operational capabilities with new knowledge," *integrating* "to embed new knowledge into the new operational capabilities by creating a shared understanding and collective sense-making," and *coordinating* capability "to orchestrate and deploy tasks, resources, and activities in the new operational capabilities" [9, p. 247]. Following [11], and in line with learning as a participative process [10], we explore dynamic capabilities as multi-level constructs, where experts in different roles, also beyond the management, are connected by productive and interpersonal dialogue for adapting to a changing environment [11].

3 Case Description and Methodology

This study is an independent part of a longitudinal, interpretive case study [12, 17] initiated in the fall of 2018 to explore organisational capability development in the context of digital transformation [18]. The case company from the Nordic region operates within the public sector and provides professional procurement and logistics services to its customers. The company employs close to 300 people in three locations. This paper reports findings from the third and final round of the overall study. The data were collected by twelve individual qualitative semi-structured interviews [12] between November 2020 and January 2021.

At the time of the interviews, the company had operated from eight to eleven months in a working mode where most of the office staff worked remotely, while the operative staff worked on-site with special protective measures. This mode we call *hybrid*, where part of the staff collaborates in a face-to-face mode and part via digital technologies. Therefore, the overall collaboration among teams is often at least partly enabled by digital tools. Prior to the pandemic, the organisation had digitalised most of its operations, and it largely functions with the support of advanced IS and technology-driven [1] tools. The transition to vast remote working by a large part of the staff required learning in terms of the new hybrid working mode practices and the active utilisation of remote collaboration tools, such as Microsoft Teams. During the pandemic, the organisation's functioning became crucial in procuring and delivering supplies to its customers, including protective gear for health care.

3.1 Data Collection

The interviews were conducted over Microsoft Teams with interviewees from both managerial and non-managerial positions. Their tasks involved knowledge-intensive work with a mix of operative-oriented and planning and coordination-oriented responsibilities. The overall goal of the interviews was to gain an understanding of how the organisation had developed during the past year.

The interview themes included topics, such as change and developing operations, IS and their utilisation, and key competencies and capabilities. In addition to answering questions according to the interview themes, the participants were encouraged to share their views also outside the themes. Due to the COVID-19 pandemic, a new theme examining the impact of the situation was introduced. This paper reports the findings related to that theme and the new hybrid mode of working. During the interviews, it became apparent that the pandemic situation was intertwined with the organisation's activities, including the hybrid working mode and the changing emphasis of core operations, so that it reflected in many of the responses in different interview themes.

The interviews were recorded by audio and researcher notes, as permitted by the participants. The recording length varied from approximately 37 min to 57 min, with an average duration of approximately 48 min. Introducing the research, addressing questions from the participants, discussing the findings from the previous interview rounds at the end of the session, and closing the session were excluded from the recordings.

3.2 Data Analysis

For the analysis, which was conducted in March 2021, the audio recordings were listened to and freely transcribed into text. The transcription was conducted as detailed notes from the recordings aiming to capture the essential responses for prompt reporting (cf. [3]). This process amounted to approximately 65 pages and 22,000 words of transcribed interview material.

The transcribed material was coded and categorised with the support of Atlas.ti qualitative data analysis software depicting items and phenomena related to the COVID-19 situation and the resulting hybrid working mode. Challenges, strategies, facilitators, and outcomes of managing the critical, prolonged situation were identified and coded as inductively as possible. [14, 19] Next, the codes were categorised in two ways. First, following Carroll and Conboy [1], normalisation process theory (NPT, May and Finch, 2009 in [1]) was utilised, as it provided a lens to understand how the new practices may have been perceived, internalised, implemented, and evaluated in the organisation. The value of NPT was in guiding us through the nuances of the data in a structured, abductive way [13]. After this way gaining an understanding of the data by their parts and the whole [17], we commenced the second round of categorisation, extracting emerging themes from the data.

The findings presented in the next section were derived from this second categorisation. They reflect the practical life and learning of the organisation in the face of 1) a critical situation affecting the society and the organisation's operations, and 2) a hybrid working mode involving new heavily technology-driven [1] collaboration and other operational practices. Finally, during writing this paper, the findings were discussed with the organisation's representatives for validation. The findings were perceived as identifiable and relevant, while some remarks were made for deepening them.

4 Findings

In this section, we present facilitators of learning to develop capabilities for functioning effectively in the technology-driven, hybrid working mode and volatile situation. The facilitators appear to manifest as immediate and evolving phenomena, and they are further divided into five different categories. In the final section of the findings, we will anticipate some long-term effects based on the interview material.

4.1 Immediate Facilitators

The *immediate facilitators* we identify as phenomena and action that were initiated soon after the COVID-19 situation escalated and the new hybrid working mode was enforced. We further describe this as *an organisational response to the situation*, including three categories of facilitators.

First, as grounding facilitators, we suggest *prompt organisational response and continued managerial action*, which refer to organisational actors anticipating and preparing for the situation, and management providing quick input and guidance to their teams. Further, management working close to the teams also in operative questions and rewarding staff under pressure were perceived as supportive measures. Importantly, open information sharing by the management enabled team members to take adequate and timely action in tackling emerging challenges in daily operations, or to provide accurate status information.

The second grounding facilitator appears to be the *readiness and commitment of staff* in the face of a critical situation. Examples of such are commitment to handle the increased, fast-paced workload and completing tasks with a high sense of responsibility. Willingness to transfer between tasks to cover resource shortages in the organisation was perceived of as helpful, while operating according to one's best knowledge as essential.

Finally, and according to the interview material crucially, *seamless, multifunctional, and continuous collaboration* appears to enable successful operations in an atypical situation. Close collaboration and information sharing with teams and customers was emphasised. Communicating, interacting, and working toward a common goal as one team as well as helping one another across organisational borders were found as keys to managing well in the situation. Table 1 summarises these findings with examples.

Table 1. Summary of the immediate facilitators with examples.

Immediate facilitators (an organisational response to the situation)		
Facilitators	*Examples*	*Interview excerpts*
Prompt organisational response and continued managerial action	Anticipating and preparing; providing quick input and guidance; working with the team; rewarding staff under pressure; engaging and sharing information openly	"[W]e pulled such a team together really quickly –" "[M]anagers have been – very close to practice –"
Readiness and commitment of staff	Commitment of personnel in the face of a challenging situation; readiness to bear responsibility; readiness to operate according to one's best knowledge	"[P]eople have – an excellent sense of responsibility –"
Seamless, multi-functional, and continuous collaboration	Close collaboration and continuous information sharing within the organisation and with stakeholders; communication, interaction and working for a common goal as a team; mutual assistance across borders	"[T]hat close collaboration was probably key –" "[Collaboration] has, indeed, enabled it –"

4.2 Evolving Facilitators

Next, by *evolving facilitators* we mean phenomena and actions that are forming as the new situation matures. These could be seen as manifestations of *organisational learning*, as the immediate factors of prompt organisational response, continued managerial action, the readiness and commitment of staff, and close, continuous collaboration are enacted.

First, the interview material indicates *increased situational and organisational awareness* resulting from the situation and focus on collaboration. It appears as a two-way street of listening to and sharing information. On the one hand, the customers are listened to carefully to identify potential sources of disruption in the supply chain. On the other hand, colleagues are internally kept updated with special care that the message is understood. Additionally, it was perceived that the awareness of the effectiveness and expertise within and of the organisation was also heightened due to the measures taken to address the unusual situation.

Second, and closely tied to the technology-driven working practices, is *learning to operate in a new hybrid working mode and volatile situation.* It appears that forming a new remote working culture and practices takes place over time, and, in this case, mostly as an organic process. Remote working is becoming part of the normal mode in the organisation in contrast to the conditions prior to the situation. Multimodal information sharing practices are implemented, also pro-actively by teams themselves, and trust in remote working practices and tools is increasing. Finally, it appears that reliable remote working tools and connections are prerequisites. Table 2 summarises these findings with examples.

Table 2. Summary of the evolving facilitators with examples.

Evolving facilitators (organisational learning as the situation matures)		
Facilitators	*Examples*	*Interview excerpts*
Increased situational and organisational awareness	Listening to the customers carefully; keeping colleagues updated; increased understanding of the big picture and effectiveness of work; increased awareness of expertise within the organisation	"[W]e keep each other on the ball all the time of surrounding events –" "[I]t is good that you have learned – what my knowledge [base] is, or someone else's knowledge [base]"
Learning to operate in a new hybrid working mode and a volatile situation	Forming of new remote working practices; multimodal information sharing; trust on remote working practices and tools; remote working mode perceived to become part of the normal	"[We] are already used to [a hybrid work mode], and practices have become routinised, and it works better" "Somehow, [remote working] has even increased collaboration"

4.3 Anticipating Long-Term Organisational Development

As the last and the temporally most far-reaching component of the findings, we briefly anticipate the long-term opportunities that the immediate and evolving facilitators may create. As the situation still unfolds while we are writing this paper, the materialised evidence of such development remains for subsequent research.

However, already at this point, we can discuss the potential *long-term organisational development* and the expected *organisational evolution stemming from the experience gained* grounded on the interview material. For instance, it would be beneficial to consider the fruitful multifunctional collaboration and utilisation of the understanding gained from the distributed collaborative practices in the future, when the enforced hybrid working mode has ceased. Table 3 summarises these findings with examples.

Table 3. Summary of the anticipated long-term development with examples.

Long-term development (organisational evolution from the experiences gained)		
Facilitators	*Examples*	*Interview excerpts*
Organisational development of collaborative culture, practices, and new working modes?	Utilising the understanding gained for the best information sharing channels; adopting new, more flexible working modes; an increased understanding of distributed collaboration	"I believe – that the [multi-functional collaboration] will continue from here on too –"

5 Discussion

In this paper, we set out to better understand *what facilitates organisational learning for developing the capability to operate effectively in an enforced technology-driven work mode during a volatile situation.* As a response, we propose a set of immediate and evolving facilitators, as well as the anticipated long-term effects that appeared in the organisation as it navigated through the sudden move to a hybrid working mode amid the COVID-19 pandemic. It appears that in this case and in the context of events, such capability forms as a result of 1) contextual base factors, such as the advanced digitalisation of operations, digital collaboration tools, and the existing expertise in the operational domain; and 2) the facilitators described in the preceding sections. The facilitators are summarised in Fig. 1.

We propose that the learning and capability development were initiated as the interaction of prompt organisational and managerial action and continued support, and the commitment and readiness of staff to operate effectively in the situation. For example, open information sharing by the management and the readiness to act with high commitment by the employees seem to have contributed to effective operations,

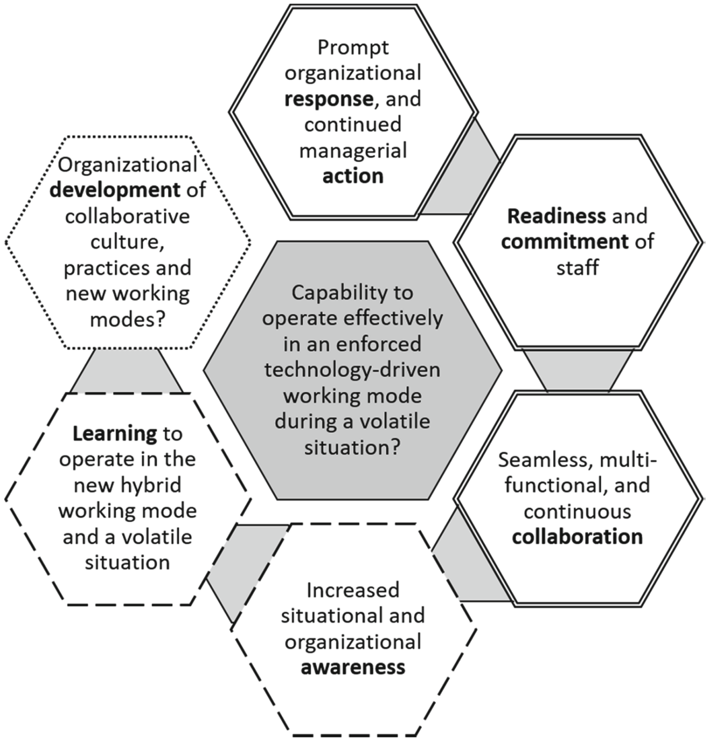

Fig. 1. Summary of the findings, including the proposed immediate and evolving facilitators and the anticipated long-term development. The first three hexagons from the top (with double lines) denote the immediate facilitators, the fourth and fifth hexagons (with dashed lines) represent the evolving facilitators, and the final hexagon (with dotted lines) marks the anticipated long-term development, as learning is accrued from the situation.

and moreover, to seamless, multifunctional, and continuous collaboration. It also appears that this combination may enable an increased situational and organisational awareness, which aligns with the learning outcomes categorised in previous research (Eraut, 2004b in [10]).

Further, it seems that as the new mode of working had been in place for some time, organisational members had learned to operate by utilising digital tools for collaboration and addressing the requirements stemming from the situation. Finally, as the long-term facilitating effect, it is anticipated that the learning gained from operating in such conditions will contribute to organisational development in terms of adopting new practices and promoting a collaborative culture. It could be asked whether, as the immediate facilitators unfold toward the evolving ones and long-term development, organisational learning could also transform from the informal toward the more structured and formal [10]. As a whole, the facilitators seem to place more emphasis on social rather than technological aspects of learning in the workplace [6].

From the dynamic capability perspective, applying the model by Pavlou and El Sawy [9], we suggest that the organisational response and managerial action stem from the capability to *sense* changes in the operating environment and act accordingly. The response and action are then translated by committed and ready staff into *integrated* and *coordinated* activity, multifunctional collaboration. As the situation was volatile with sudden changes both in the mode of collaboration and task priorities, we suggest that *learning* happens iteratively around the immediate facilitators. In terms of the evolving facilitators, as awareness of the situation and organisational expertise increases, it appears that the *sensing* capability is strengthened. We further suggest that in time, new hybrid working mode practices are *learnt*, which both feeds back into daily operations and the immediate facilitators, enabling the *integration* and *coordination* of refined practices as longer-term organisational development.

Finally, we may see these processes as two connected cycles of dynamic sensing, learning, integrating, and coordinating capabilities [9]. In the immediate facilitators, the capabilities are exploited for quick action, and in the evolving facilitators and long-term effects, they are strengthened to enable the further refined practices. This could lead to a "virtuous circle" [11, p. 1745], where through the productive and interpersonal dialogue of employees in different roles, the input of individuals accumulates into an organisational dynamic capability [11], enabling effective response to environmental change (cf. [7]).

6 Conclusions

The paper presented the findings of a qualitative case study, the immediate and evolving facilitators of organisational learning to develop capabilities for operating effectively in an enforced, technology-driven working mode and a volatile situation imposed by the COVID-19 pandemic. The paper explicated the findings theoretically from multi-level dynamic capability [9, 11] and workplace learning [6, 10] perspectives.

As limitations of the study, we wish to highlight two main aspects. First, even though we discuss how learning and capability development may have happened in this case, events have likely taken place in an interlinked, emerging [10, 11] manner. Thus, we refrain from claiming causal relationships. Second, the handling of risks and challenges was excluded from the paper due to space constraints. The risks and challenges, and their potential impact, should be addressed in subsequent work. For example, the endurance of staff, ability to drive new development activities, and induction of new team members may pose challenges if the enforced situation is prolonged.

While we can see the linkages of organisational learning and capability development, further research would be required for a more solid understanding of the antecedents of such agility and the role of digital technologies in it [15]. For example, do the antecedents lie in the previous experiences of the organisation or the existing knowledge the organisation has harnessed in a new situation? Next, what about collaboration as a facilitator; is it immediate or evolving? Here it was categorised as immediate, as it was perceived of as key, and it initiated quickly. Further, longitudinal research is required to uncover how the anticipated long-term effects grow in the aftermath of the situation. Additionally, a more elaborate analysis with learning typologies, such as discussed by Tynjälä [10], should be incorporated. Finally, while the NPT frame [1] was utilised in the early stage of the qualitative analysis, it turned out that an inductive approach provided a more practice-oriented insight into our interview material. However, NPT appears as a viable model and its utilisation should be further explored. It seems likely that it would yield more understanding on the mechanisms of adopting new practices in organisations.

By connecting the research streams of workplace learning [6, 10] and dynamic capabilities [9, 11], we explored the effects of a sudden and enforced transition to a technology-driven work mode [1, 2] in an organisation. With this, we wish to contribute to research on organisational learning and capability development processes in technology-intensive and volatile operating conditions, which require the capacity of organisations to learn and adjust rapidly [7]. As implications for practice, we propose a new understanding for management in navigating through such situations. While further work is still required, we believe this case will inspire discussion in the scientific community regarding organisational learning.

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Digital Transformation of Education and Learning Through Information Technology in Educational Management

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Abstract. 2021 is a year of anniversaries in the IFIP family. IFIP TC3 WG3.7 is 25 years old. Celebrating anniversaries is a good opportunity to reflect on how far we have come, and what the future holds. The incorporation of digital technology in education reflects an evolution of light and shadow, with many challenges for the future. Information technology has not only been present in the field of education as a teaching-learning tool, but has also played an important role in educational management. This paper analyses the contribution of IFIP TC3 WG3.7 to the development of the field of Information Technology in Educational Management. It contextualises its origins within the framework of the evolution of digital technology and analyses the most recent situation. The challenge for the future is to reflect on the possible contribution of contemporary educational management trends to help create a balance that facilitates the implementation of digital technologies in education while meeting the social objectives that give meaning to the educational system.

Keywords: Information technology · Educational management · WG3.7

1 Introduction

In 2021, the Working Group 3.4 (WG3.4) of the Technical Committee 3 (TC3) of the International Federation for Information Processing (IFIP) celebrates its 50th anniversary. During its years of existence, WG3.4 has successfully contributed to the creation of knowledge in the field of Professional, Higher and Vocational Education in ICT. Numerous publications attest to this, as well as a remarkable number of international conferences and events in which researchers and practitioners from all over the world have contributed. Interestingly, one of the most relevant results of WG3.4 was the birth of a new Working Group within TC3. In 1994, WG3.4 organised a conference in Jerusalem with the theme Information Technology in Educational Management (ITEM). The conference aroused a great deal of interest in the scientific community and during the conference there was a high level of agreement on the importance and timeliness of the chosen topic. This interest led to the creation, after its approval by

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IFIP in 1996, of the Working Group 3.7 (WG3.7) focused on the discipline of Information Technology for Educational Management. The year 2021 is therefore also an important anniversary for WG3.7, namely its 25th anniversary.

The Open Conference on Computers in Education 2021 (OCCE2021 DTEL) is a good opportunity to celebrate such an important date for WG3.4, the host of the conference, and for WG3.7, both of which are linked by close ties. The conference is also a good opportunity to reflect on the contribution that WG3.7 has made to the Digital Transformation of Education and Learning over the past 25 years. Schools, high schools and universities prepare students for the world of the future, and this requires the management of educational centres for the upcoming years. The digital transformation of education and learning has necessarily been linked to a process of digital educational management, which has also had to adapt to new technologies. From the beginning of the existence of WG3.7, it was established as a premise that the focus of the research would be on the impact of information technology for educational management on the teaching-learning process. However, after 25 years, questions can be raised as to whether the use of digital technology (DT) in educational management is the same as the use of DT in business management. There are many parallels between the two types of management, although perhaps the biggest difference lies in the tempus or time lag between the implementation of new management techniques in business and education.

This paper reviews the topics of research interest in information technology in educational management in the past and present, as well as considers foreseeable future trends. Parallel to the review, the contribution of WG3.7 in this arena is described - the Annex 1 summarises the conferences organised by WG3.7 and the books published in these 25 years. Finally, a conclusion is offered on the potential role WG3.7 can play in new scenarios.

2 Information Technology for Educational Management: Origins

Educational management is a broad field that, as its name denotes, encompasses two converging disciplinary areas. The appropriate management and administration of educational institutions has been a matter of concern since the creation of the modern educational system all around the world. Independently of the profit or non-profit nature of schools, universities and other educational centres, the need to efficiently invest in certain resources with the purpose of providing an effective socio-economic education to citizens, has grown a body to manage and administrate the educational process. Educational management includes managing the internal work of educational institutions (budget, personnel, infrastructures, strategies, goals) as well as their external work (external stakeholders' demands and needs, goals coherence within a broader educational setting, policies). Another dimension to be managed in the educational arena has to do with teaching and learning aspects of the education process, i.e. the promotion of best educational practices by part of teachers and trainers to achieve the educational goals. These goals are set by the policies and strategies stated externally and internally to educational centres. The educational picture widens as societies increase their complexity.

In the educational setting, technology, to a greater or lesser extent, has always be present (buildings, papyrus, abacus, pencils, slide rules). With the development of computer technology and its popularisation because of the continuously decreasing costs and improved performance, digital technology has become an additional actor in the educational arena, accompanying the work of teachers and educational administrators and managers. Although no universal definition for information technology for educational management has been provided, the term may include the combination of computing and communication hardware and software adapted to support the administration and management of internal and external work of educational institutions. The beginnings of the use of information technology for educational management date back to the 1970s [1]. At that time, some teachers created the first amateur school administration programs for their own schools or colleges, and also in some university departments. At the end of that decade, software providers entered this market by producing software adapted to more professional standards. Some developed countries had school software applications in place in a large number of schools by the end of the 1970s. These applications were primarily for administrative purposes. In the 1980s, with the commercialisation of personal computers, there was a period of expansion in school computing. At this stage, office and administrative computer applications were used with the characteristic that they were not integrated with each other. The lack of integration limited the possibilities for management support, as managers needed to identify relationships between data. During the initiation and expansion stages, the main objective of software development was to improve the efficiency of school office activities. The next stage, the integration stage, can be characterised by information management and the integration of computer modules with administrative and teaching functions. In those years, educational authorities in technologically advanced countries became aware of the importance of information technology in the field of educational management, and invested large sums of money in the improvement of school computer systems [2, 3].

Parallel to the development of information technology for educational management, academic interest in this field was growing. In 1994, the first International Conference on Information Technology in Educational Management was held in Jerusalem, where the creation of WG3.7 was conceived. Subsequently, in 1995, at the World Conference on Computers in Education held in Birmingham, a considerable number of papers were presented on this topic. A professional group of 20 experts from ten different countries worked during the conference to produce a report addressing the development, research and implementation issues central to the continued growth of information technology for educational management. The report also proposed research methods and strategies needed to generate the desired knowledge and understanding.

In the last decade of the 20th century and the first decade of the 21st century, the use of information technology for educational management grew enormously in industrialised countries. Also, since the beginnings of the 21st century, developing countries began to utilise the potential of these systems, with very high levels of use in countries such as Botswana and Uganda [4].

Typical data processing functions in schools during the early stages of the uptake of educational management information systems included [1]:

1. Updating of the computer database with affiliation information of students, educators and support staff.
2. Retrieval of information and production of documents to obtain information on the situation of the school.
3. Support to the decisions of the educational managers based on the available information.
4. Internal communication within the educational community and external communication to stakeholders of the educational system.
5. Student monitoring systems by assessing students' progress over the long term. This function was considered as one of the most important, as it enables the management of data on student progress. Technology facilitates the production of student progress reports, which can be used by both teachers and school management.

Special mention should be made of the research carried out on information technology for educational management in the sphere of the activities organised by WG3.7. The most popular topics over their first ten years were Assimilation and integration of DT into educational management, followed by Assessment of DT support to educational management, DT applications in educational management, and National, regional and local experience in the use of DT for educational management. All together these topics represented 76.2% of all papers (117) included in the publications by WG3.7 during their first ten years of existence. The most recurrent topic was the Assessment of DT support to educational management, which was repeatedly dealt with because of the importance of analysing the results obtained after implementing new strategies, policies, techniques or tools [5]. Annex 2 describes the research topics covered primarily by WG3.7 members during the initial period of activities. Further information about research methodologies and main contributions that were put forward during this stage can be found on [5].

3 Information Technology for Educational Management: Maturity

Whilst progress is clearly marked during the origins of the field, some common elements requiring development remained. In particular, the following issues were common concern during the transition stage to maturity [6]:

1. Use of the management information systems (MIS) limited to administrative tasks.
2. Lack of MIS availability to all teaching staff.
3. Unsuitable training and support.
4. Inappropriate software interface.
5. Usability and functionality limitations.
6. Inadequate reporting and decision support facilities.
7. Lack of user-centric implementations.
8. Minimal interoperability with other systems.

A review of the literature related to the field of information technology for educational management shows that the main driving force is information technology. The vast majority of publications are related to the description of new software applications or the results obtained after applying a particular information technology in an educational context. The number of publications related to the incorporation of new management theories in the educational arena is very small compared to those dealing with educational technology. Also, many publications referring to recent trends in the field of management that have been put into practice in the educational management area have, as their background, the use of some form of information technology as a supporting tool. Information technology has been growing steadily both in terms of computing power and its incorporation into people's daily lives. The spectacular development of the Internet and the rise of social networks has also had a decisive influence on educational management. On the other hand, one of the greatest advances in information technology has been the integration of information among previously isolated systems.

The opportunities provided by information technology in recent years should not obscure the risks inherent in the massive incorporation of digital technology in education. Teachers' use of technology can be uneven. Some instructors design effective and creative learning opportunities for their students that precipitate deep thinking and reflective engagement in the development of conceptual knowledge. However, some use digital technologies as shortcuts to learning, without focusing on intended outcomes. For example, some educators do not deliberately teach effective online search and verification strategies, nor are they even aware that they should, nor do they know how to incorporate such practices into classroom work. Some teachers, especially at secondary level, struggle to see beyond the content of their subjects, looking only for content-oriented digital solutions, rather than how they might enhance students' own abilities to problem solving, critique and create knowledge with expert guidance [7].

Moreover, many technology companies have turned their attention to education, given that, because of its volume, it can be a lucrative business. Large firms with an interest in education constitute what have come to be known as big Edtechs or Lordtechs. Most of the software applications currently used as learning and educational tools are practically the same all over the world. The influence and ability of big Edtechs to reach all geographical areas has made this possible [8]. All of the above is an element of concern for those responsible for educational management, who must ensure that information technology does not become a mere commercial instrument that prevents the real objectives of the education system from being achieved. However, it is worth highlighting the information technologies that have played a leading role in recent years, given that they have influenced and, foreseeably, will continue to influence the educational process and, therefore, are and will be the object of attention from the perspective of educational management. Weller [9] identifies the most influential educational technologies developed in the last twenty years, with their lights and shadows: E-Learning, Learning Objects, Open Educational Resources, Blogs, Learning Management Systems, Video, Web 2.0, Second Life and Virtual Worlds, E-Portfolios, Twitter and Social Media, Personal Learning Environments, MOOCs, Learning Analytics, Digital Badges and Artificial intelligence. From the mentioned technologies, Learning Analytics and Artificial Intelligence are having an increasing weight in the educational management arena and, very likely, they will constitute critical tools supporting for decision making in this field [10–12].

In this period of maturity, research on information technology for educational management has followed the path of technological development. In the sphere of the conferences organised by WG3.7, the most popular topics over their second ten years of existence have been Assimilation and integration of DT into educational management, DT applications in educational management, and DT applications for teaching. Although the latter is not directly related to the scope of the WG 3.7, this theme gradually has gained importance [13]. Annex 3 describes the research topics covered primarily by WG3.7 members during the maturity period. Further information about research methodologies and main contributions can be found on [13].

4 Information Technology for Educational Management: Future Trends

The rapid development of technology and the constant innovation and application of computer and information technology make information technology change the future lifestyle of human beings and induce comprehensive changes in human learning. The promotion of information technology education policy will enable education to present a new appearance of learning [14].

Drawing on current technological developments and existing applications in digital education, such as mobile apps, learning management solutions and anti-plagiarism software, Popenici and Kerr [15] raise the critical question of who will set the educational agenda in the future, i.e. corporate companies or educational institutions. Large digital and technology-driven companies such as Netflix, Samsung, Google, Microsoft and Facebook, also referred to as Lordtechs, are seeking to develop new data-driven learning programs that enable new teaching tools in public institutions through the optics of these business-driven companies [16]. For example, the Netflix group developed the DreamBoxLearning program for mathematics in the US market, which enables personalised learning based on Artificial Intelligence (AI) technologies with an adaptive intelligent learning system. That these Lordtechs are investing heavily in the development of AI-based teaching and learning solutions inevitably raises the question of whether educational institutions are prepared to implement such data-driven technology in their teaching and learning programmes [17].

This leads one to consider the importance of the challenge facing educational institutions if they are not to become mere instruments of the decisions taken at Lordtechs' headquarters. One possible answer lies in the importance of strengthening the knowledge and skills of future educational managers through a structured training process. In this respect, it could be pointed in two research directions [18]:

1. To analyse the level of training of modern managers in accordance with the requests of the society on DT competences of managers in the educational system.
2. To analyse the problems of selection and application of professionally oriented information technologies in the educational process to meet the needs of educational stakeholders (students, educators, society).

Moreover, the importance of national responses to these challenges should be anticipated. Schools and higher education systems are continuously confronted with the growing challenges of preparing students to successfully participate in the digital age. In many countries, this is leading to multiple efforts and changes in national policies regarding the integration of DT into education systems [19]. Educators, researchers and policy makers believe that the full potential of educational technology will ultimately only be realised when educational policymakers, administrators and teachers effectively integrate and authentically incorporate technological improvements along with data science concepts into their practice and curriculum [20].

It can be expected that alongside the commercial interests of the Lordtechs, national policies align as frameworks for establishing the objectives and limits to the indiscriminate implementation of new technologies in education. The agents that can serve as a means to align both legitimate kind of interests may ultimately be the educational managers, because of their proximity to the reality of students' and educators' demands to consume the latest available technology, but also as guardians of the social interest of national education systems. It is on this latter aspect that the research activity of WG3.7 may focus part of its future activities.

5 Conclusions

Information technology for educational management offers solutions for a wide range of activities at different levels of education - primary, secondary, higher education and adult learning. The broad spectrum of needs to be covered by providers of technology solutions for educational management means that there is no single product that can cover all needs. Moreover, it could be considered that the search for such a single product is a naive and unachievable goal. However, it is necessary to assume that the need to develop multiple products to meet the different demands of the educational management field implies that these have a low level of data integration with each other, at least in their initial stages of development.

Looking back, it can be concluded that in the field of information technology for educational management the technological part of the sentence has been the most prominent. Most of the innovations in this field have been technology-driven. Sometimes they have been accompanied by strong educational frameworks, but sometimes they have only been technologies in search of an application. It is also true that, from an educational management perspective, the social impact of promoting or implementing a technology beyond its uses as an educational tool has often not been addressed. The widespread adoption of technologies such as social networks, MOOCs, learning analytics and AI have social implications that educational authorities have often been unable to appreciate. It is therefore necessary to learn from the past and anticipate the future by studying the social and educational implications of emerging technologies. A good example in this regard is the initiative carried out by IFIP's TC3, under the name of Zanzibar Declaration, which involves a large number of actors in the educational arena to reflect and expose their concerns and recommendations to identify the social and educational implications of technologies such as Big Data, Machine Learning, Autonomous Systems and Artificial Intelligence, among others. Therefore, the challenge facing the discipline of information technology for educational management, and for WG3.7, is to better balance digital technology with conceptual frameworks, both managerial and educational pedagogies, and social movements.

Annex 1 Conferences and Publications Led by WG3.7

Venue	Year	Book title	Editor
Jerusalem (Israel)	1994	Information Technology in Educational Management	Chapman & Hall
Hong-Kong (China)	1996	Information Technology in Educational Management for the Schools of the Future	Chapman & Hall
Maine (USA)	1998	The Integration of Information for Educational Management	Felicity Press
Auckland (New Zealand)	2000	Pathways to Institutional Improvement with Information Technology in Educational Management	Kluwer
Helsinki (Finland)	2002	Management of Education in the Information Age: The Role of IT	Kluwer
Gran Canaria (Spain)	2004	Information Technology and Educational Management in the Knowledge Society	Springer
Hamamatsu (Japan)	2006	Knowledge Management for Educational Innovation	Springer
Darwin (Australia)	2008	Evolution of Information Technology in Educational Management	Springer
Kasane (Botswana)	2010	Information Technology and Managing Quality Education	Springer
Bremen (Germany)	2012	Next Generation of Information Technology in Educational Management	Springer
Guimaraes (Portugal)	2016	Stakeholders and Information Technology in Education	Springer

Annex 2 Number of Papers Classified by Research Subject Published by WG3.7 (1994–2004)

Topic	Number percentage (%)
Strategies to integrate IT into educational management	9
	7.7
Assimilation and integration of IT into educational management	27
	23
ITEM state of the art. The discipline's present situation and trends	3
	2.7
Assessment of IT support to educational management	20
	17.1
National, regional and local experience in the use of IT for educational management	18
	15.4
IT applications in educational management	20
	17.1
Mathematic tools employed to make models for educational management	6
	5.1
IT applications for teaching	8
	6.8
Teacher and manager training in the use of IT for educational management	6
	5.1
Total	117 100

Annex 3 Number of Papers Classified by Research Subject Published by WG3.7 (2006–2014)

Topic	Number percentage (%)
Strategies to integrate IT into educational management	7
	7.3
Assimilation and integration of IT into educational management	26
	27.1
ITEM state of the art. The discipline's present situation and trends	3
	3.1
Assessment of IT support for educational management	9
	9.4
National, regional and local experience in the use of IT for educational management	5
	5.2
IT applications in educational management	20
	20.8
Mathematical tools employed to create models for educational management	4
	4.2
IT applications for teaching	16
	16.7
Teacher and manager training in the use of IT for educational management	6
	6.3
Total	96 100

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