Adapting an OER Textbook for the Inverted Classroom Model – How To Flip the Classroom with BBC micro:bit Example Tasks

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***Abstract*—Full Paper Research-to-Practice**

The current COVID-19 crisis has created significant challenges for schools. The growing importance of "flipping the classroom" and the needful emphasizing of online-learning were owed to the situation. To meet these requirements, materials and tasks must be adapted. The Open Educational Resource (OER) textbook "Computational Thinking with the BBC micro:bit" was developed for the introduction of Computational Thinking (CT) for 10-14-year-old pupils in Austria's secondary schools. Example tasks in the textbook are designed with an open end and present extensions with ideas for further development instead of ending abruptly. This article provides a guideline for a clear distinction in redesigning existing lessons following the Inverted Classroom Model (ICM) using videos for pre-class work and live task extensions for in-class work. Which parts in the learning design must remain as live lessons and which parts can be adapted for video lessons? The respective research shows that examples that have a makerspace activity as an extension are especially helpful for an efficient determination of the appropriate part in the learning design and particularly suitable for an adaptation with ICM. The central advantage of the ICM is that it responds flexibly to the individual learning needs of each student. It allows students to take their time reviewing the material at their own pace without getting left behind. The textbook used here encourages pupils to find their own solutions by explorative learning using the block-based programming environment MakeCode. Additional information to be uncovered by the learner is provided for every single step in the accompanying online wiki website. Results from observations showed that this uncover-function, being a central element of the online material, encouraged the learners to explore their own way in finding a solution with playful elements and increased motivation. The many haptic elements of a makerspace activity are in particular useful for consolidation of the learned and are predisposed for in-class work and deepening the understanding following the constructionism theory. A Design-Based Research (DBR) approach is used to create and evaluate the redesign of a proven example task in a pilot project. Teachers, who are already familiar with the BBC micro:bit and the OER textbook, were trained on how to use the "flip-version" of an example task in their lessons and asked to develop a lesson plan for implementation. The didactic approach to redesigning the material and teacher training was evaluated during the first cycle of DBR. Results from expert interviews showed that the redesigned material and training deliver a solid ground for rework and further research on a larger scale.

***Index Terms*—microbit, inverted classroom, flipped classroom, makerspace, block-based programming, computational thinking, computer science**

I. Introduction

In Austria's lower secondary schools Basic Digital Education (BDE) entered the classrooms in 2018. Due to a new curriculum for 5th to 8th-grade students, one essential change for Computer Science (CS) and Informatics was implemented – the introduction of the new subject Computational Thinking (CT). According to the curriculum, CT should not necessarily be exclusively taught by specialized teachers like informatics or mathematics. Teachers from all other subjects should use interdisciplinary lessons where possible for teaching CT. Especially those teachers with a weak background in CS and informatics need proper guidelines, good examples, and solutions to build up knowledge and confidence in dealing with CT at the same time.

To promote and smoothly introduce Computational Thinking for 10-14-year-old pupils an Open Educational Resource (OER) textbook on Computational Thinking with the BBC micro:bit was developed [1]. This book and its accompanying wiki website [2] are used as the primary resource in the supporting project "Learning to think, solving problems", in German: "Denken lernen, Probleme lösen (DLPL) Sek 1". Twenty-two ready-to-use examples are available in the textbook and wiki for in-service teacher training and classroom use with students later on.

The wiki website [2] uses elements of inquiry learning to encourage an explorative, playful approach when finding a solution to a formulated problem. To cope with different learning styles and the individual pace of students, the examples of the textbook, once solved, have an open end with additional exercises. In this ending, extensions or enhancements of the originally stated problem are listed to further stimulate new ideas and foster the demand for research and action. The more haptic extensions in form of a makerspace stimulate getting into action while consolidating the learned [3]. In the following, we will demonstrate how the makerspace activity is used for a clear distinction and separation of learning content for live teaching and video or remote teaching. We will show the adaption of a textbook example according to ICM and the redesign process for video and live teaching phases [4]. This approach provides more flexibility to the individual learning needs of students given the current COVID-19 pandemic crisis and the resulting need for more online-learning at one's own pace.

II. Theoretical Background

A. Flipped Classroom – Inverted Classroom Model

Traditional learning scenarios in education base on the following two steps: First, a theoretical input is presented by a teacher, followed by some small exercises as in-class work. Second, the deepening of theoretical understanding is achieved through further exercises as homework. Out-of-class the theory learned is practiced and applied without the active help of a teacher. Flipping the classroom and applying the inverted classroom model simply swaps in-class and out-of-class content. With the help of technology, in-class activities are moved outside the classroom [5]. In common delivery scenarios, educational material such as videos and tutorials with direct instructions are assigned for pre-class work to complete followed by active participation in learning activities for in-class work [6].

In the following, the terms flipped classroom or inverted classroom model (ICM) will be used synonymously, meaning a primary focus on information transfer out-of-class and student-centered learning activities in-class [7] for consolidation of the learned and active knowledge creation [8].

B. Computational Thinking

The increased use of the term "computational thinking" (CT) in the educational context was generated by Jeannette Wing in 2006 in the journal "Communications of the Association for Computing Machinery (ACM)". With the article, Wing presented *"… a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use."* [9]. The idea and mental concept behind CT originate back to Seymour Papert, who also invented a visual programming language named Logo with his book "Mindstorms: Children, Computers, and Powerful Ideas" [10]. Furthermore, Papert [11] developed a learning theory called constructionism building on the constructivist learning theories from his mentor Jean Piaget. The constructionism theory links the main parts of this research together, i.e. visual programming with the micro:bit, inquiry-based learning, flipped classroom, makerspace activities, and computational thinking.

The development of a common CT definition [12] is still not seen as completely settled, but over the past few years, a fairly consistent picture in defining CT has emerged and CT is getting more and more demystified [13]. The here used different aspects of CT are comprised of Decomposition, Abstraction, Algorithmic Thinking, Evaluation, and Generalization. This definition emphasizes the importance to see CT as a general thought process and a systematic approach to solving problems. In the most recent research, Li et al. [14] investigated CT definitions and concluded that it is more a mental model of thinking with their article *"Computational Thinking Is More about Thinking than Computing"*.

C. Inquiry-based Learning

The 5E instructional model [15] for inquiry-based learning (IBL) is used as an integral part of the proposed learning design. The 5E learning cycle (figure 1) consists of five phases starting with engagement, exploration, explanation, elaboration, and evaluation. The framework of the 5E model provides enough flexibility for the teacher to use open, guided, or direct inquiries depending on actual needs. Schallert et al. [16] provide a guideline to merge flipped classroom approaches with the 5E inquiry model. This approach is used throughout the following, except where not applicable e.g. not examined post-class work for this study.

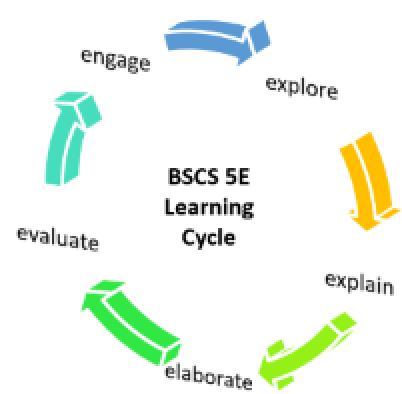

Figure 1. 5E Learning Cycle, based on 5E Instructional Model BSCS [17]

The provided learning material, i.e. the OER textbook and the wiki website [2], uses a combined approach to foster interest in further investigation and exploring playfully when solving problems. First, the book as a hardcopy contains only a subset of the available material for an example task with the BBC micro:bit, but enough to understand the given problem and getting started. Second, the wiki website based on the textbook uses additional material, but to be uncovered by the learner as needed. This is accomplished through "spoiler" hyperlinks that must be clicked before new information is accessible. An emphasis on student-centered and self-driven learning pathways through the material is thus achieved [18].

D. Makerspace Activities

Activities with a possible workload for makerspaces or fabrication laboratories (fablabs) are ideal for supporting the flip of a traditional classroom example task. The prerequisite is that the overall task can be adapted for the flipped classroom, which will be described in detail later. Makerspaces can be compared to places like a garage, studio, or workshop where all the tools for elaborating the work-piece are permanently installed and accessible. Today, this includes digital tools like computers for programming, single-board devices for control and steering, 3D-printers, and the like [19]. Traditional tools that are needed for physical workmanship are also available including small electronic components that may need soldering [20].

In makerspaces, the focus is set on the concrete, actual work on a product that today can also exist in the virtual space – like a program part for remote control or a complete app as the final product. This "learning by doing" approach refers to Seymour Papert and the constructionism learning theory by emphasizing the importance of the learner's active role in the learning process [11]. Making is not solely about tinkering, but more specifically about digital do-it-yourself leaving enough room for creativity and playful learning. Creating new solutions for specific problems that can be worked collaboratively is the central goal of making. Transferred to schools, this affects that teachers do not act as experts but as co-designers of the solutions. There are no right or wrong solutions available but the process of finding one with collaboration and discussion – or even failure [21]. Maker education is therefore project-oriented and requires open learning environments with a high degree of interdisciplinarity [22].

III. Methodology

The "flip" implementation of a newly redesigned example task is investigated utilizing focus group and expert interviews. Further refinement and rework of the material will lead to a theory to be investigated in follow-up research on a larger scale.

The following questions are explored: How is it possible to adapt an existing textbook example task for teaching with ICM? Which parts in the learning design of the task must remain as live lessons and which parts can be adapted for video lessons?

A. The Study

An in-service teacher training was offered by the University of Education Lower Austria, that fifteen teachers attended. The teachers were already familiar with the micro:bit before attending, i.e. how to program and how to use it live in classroom teaching. Based on the quality criteria for teacher training and professional development [23], the workshop was set up in three different phases: theoretical input, practical work, and reflection. Since the combination of makerspaces and the computing device is completely optional for the original project, Kastner-Hauler [24] designed a workshop to acquire hands-on experience and a deeper understanding of the material adapted, with consideration of the 3-2-1 model of didactic elements [25, pp. 335–339].

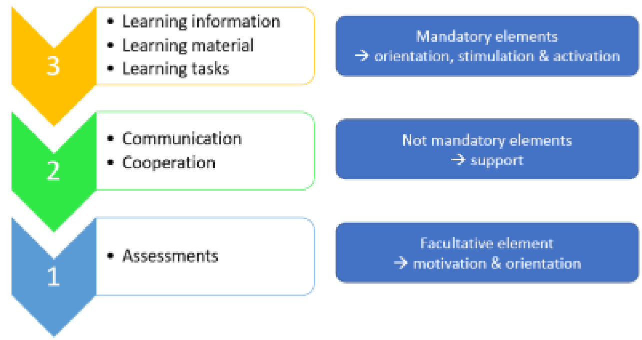

Figure 2. 3-2-1 model of didactic elements for learning offers, Kerres [25]

Regarding the model in figure 2, a didactically designed learning offer consists of (3) three basic mandatory elements: *learning information, learning material, and learning tasks*. Then (2) two additional optional elements follow: *communication and cooperation*. Lastly (1) one facultative element concludes the model: *assessments*. The model, originally designed for expository learning offers, can also be applied to explorative or inquiry-based learning offers up to the university level [26].

In the workshop from Kastner-Hauler [24], the participants were therefore put in the role of active learners [23] to generate new knowledge [27, pp. 56–83] about how the parts of the newly designed learning material fit together. To focus more on the makerspace activities a flipped delivery was chosen for implementation. After the workshop, the teachers were asked to plan their own lessons given the additional information from the training. To evaluate the in-service teacher training workshop, focus group interviews with the fifteen participating teachers were carried out.

Five teachers planned their lessons according to the request and provided active feedback. All the participants are proven subject matter experts [28]. The feedback was then collected using interviews with semi-structured guidelines [29] that derived from the focus group interviews after the in-service teacher training workshop. Initial questions checked for the validity of basic conditions for feedback, i.e. "Have you read, watched, and tested all parts of the material yourself?" and "Are you familiar with the example task in question, the one to be redesigned for a flipped classroom delivery?". Then nine questions followed to the redesigned ICM material and the personal opinion of the subject matter expert. Overall, the nine questions contained the common theme "Is the redesigned ICM material ready for use in class?" and "What needs to be changed for class use when planning an own implementation?". The full questionnaire can be requested from the first author.

The interviews were recorded and transcribed with the consent of the participants. The written responses were then evaluated using qualitative content analysis according to Mayring [30]. For this purpose, the answers were first generalized and reduced to essential core statements, so that categorization was possible [31, pp. 209–213]. The categories were formed in several loops, first deductively, then inductively, and were based on the content areas of the questionnaire [32, pp. 97-114]. For this purpose, the first and second author coded the written interviews together in the following three steps. After (1) joint coding the first interview and establishing a written coding guideline, both authors worked independently on the second interview and compared the results. (2) The coding and category building were then revised followed by a re-coding of the first three interviews. The comparison hereafter achieved an intercoder reliability rate (IRR) of 81.6 percent and after (3) last revision of coding instructions the final IRR of all five coded interviews showed 90.8 percent. The calculated Krippendorff's alpha [33] comparing the two researcher's binary coded data achieved a value of 0.813. This value is acceptable for evaluation of the first cycle in a multi-cycle DBR-study.

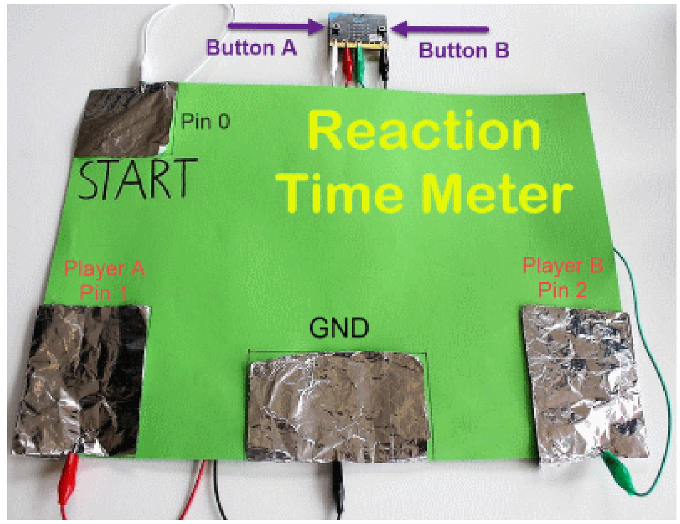

Figure 3. Reaction Time Meter, Bachinger and Teufel [2] - with extensions

B. Materials

In this study, the OER textbook *"Digitale Bildung in der Sekundarstufe - Computational Thinking mit BBC micro:bit"* [1] is used as a basis for testing the flipped classroom application with makerspace extensions. Bachinger and Teufel [1] present each individual example task with an open outlook on possible extensions as a wiki website [2]. Under the heading "further development", suggestions for possible extensions and adaptations of the tasks are listed as examples. For the practical implementation and testing of ICM, the example "Reaction Time Meter" was selected here. However, with slight modifications, any other task of the textbook can be used as well. If the selected example is missing the makerspace activity even in the list of possible extensions, there is the need to create one. This should not be too difficult to accomplish when looking at other examples of the book.

A possible solution and final outcome of the completed makerspace activity for the chosen example is shown in figure 3. Once the makerspace activity is determined, the task is broken down into meaningful parts such as programming and making. It should be accomplishable to solve the resulting two substeps independently from each other. Once the parts that lend themselves to flipped implementation for pre-class work have been identified, further adaptations may be possible and necessary.

First, a reduction to the technical possibilities available in the flipped phase must take place. In this example, the sole programming of the example without the makerspace part using a web browser was chosen. Since the programming environment also includes a simulator for the micro:bit, this is ideally suited to create the program on its own without physical access to the micro:bit device. Only a computer with an internet connection and a browser is required for pre-class work at home.

Furthermore, it should be mentioned that implementation without prior experience with the micro:bit and the programming environment MakeCode [34], i.e. a jump start, is not suitable and not recommended. The conceptual comprehension and the experience of the matter are generally better supported by previous live lessons, followed by virtual learning [35]. After a short settling period and the successful completion of three to five simple examples, one can build on the made live experience and transfer it to a virtual environment, such as a flipped video or a tutorial. Experience has shown that this point can occur already after two to four lessons, allowing for implementation as in the following subsections.

a) Adaptions for pre-class work: The example "Reaction Time Meter" uses self-made, external aluminum pads connected to the micro:bit through cables with crocodile clips. The so enlarged buttons serve as triggers for program control and metering the reaction time (figure 3). The external aluminum pads are not available for the flipped phase (self-study) and needed replacement by using the buttons in the simulation of the micro:bit instead. Figure 4 shows the block-based code of the programming environment MakeCode for pre-class work before and after the adaption for in-class work (Button A is replaced by Pin 0, which is connected to the aluminum pad). Likewise, the two-player variant of the example was omitted for pre-class work to reduce complexity. Short video tutorials are used for self-study. Didactically there is no need to include a second player variant of the program. Later copying of the code and changing the name of the button from "A" into "B" and likewise adaptions after copy operations are very easy to accomplish. Implementing the two-player variant later takes only a small amount of effort and time.

Building on the companion wiki, a written tutorial is created as initial support for the video, incorporating all of the previously mentioned adaptations. The written tutorial also serves as a script for the video recording, which visually depicts the work instructions using a flowchart description adapted from the wiki. As second and optional support offering, an additional video is provided to repeat the topic of flowcharts for programming if needed.

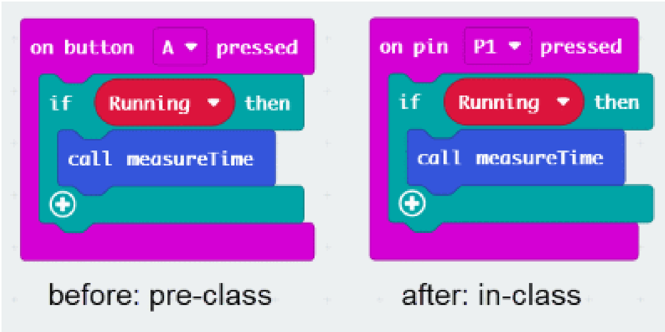

Figure 4. Code Comparison, MakeCode [34] - with extensions

The flipped video refers to the tutorial, which lists all the individual steps. The tutorial, like the wiki, is also enriched with spoiler links that expand and reveal the exact procedure only when the link is clicked. This procedure encourages learners to use only additional information in the tutorial when they need more information and the first visible description does not provide sufficient instructions for them. If this is still not enough to form a solution, the final code and images of a solution are offered in form of a picture gallery at the end of the tutorial. This is the third support offering and allows to possibly find last, small errors by code comparison.

The three support offerings in addition to the flipped explanatory video are: (1) tutorial with spoilers, (2) optional flowchart video, (3) final code as pictorial. These three building blocks form the basic framework for the explanatory video according to ICM. This video is enriched with the help of intermediate questions as didactic interactions. Thus, passive viewers become de facto active learners. These interactions were embedded directly into the video – here exemplarily with H5P [36].

b) Adatptions for in-class work: For live in-class work, it is essential to carry out a reverse translation of the adaptations that were previously undertaken. In the provided example, this mainly concerns the conversion of the program control and metering from the buttons of the micro:bit to the external aluminum pads with crocodile clips according to the tinkering instructions for the makerspace.

In this phase, the focus is on refreshing and deepening the learning content previously acquired by the participants themselves. Possibilities for makerspace expansions can gradually develop in the course of active work far beyond the example specifications. Targeted intervention by the teacher acting as a learning coach can provide new ideas and encourage further research and experimentation.

C. Research Design

The design-based research (DBR) approach is used for the flip redesign of an example task [37]. The results from the first cycle of theory development and planning of implementation are presented and discussed. Subject matter experts were asked to provide feedback which was collected using the qualitative techniques of focus group and guideline-based interviews [28]. Since DBR has more cycles for developing and refining a theory, the presented research is not yet fully completed. However, the outcome of the first cycle is evaluated and the feedback is used for rework, refinement, and further examination on a larger scale in the next cycles to come.

IV. Results & Discussion

All five participants qualified as experts for the qualitative interviews as they actively participated in workshops from the first author. The presented core concepts of the micro:bit, the OER textbook, and wiki are very familiar to them. The flipped redesign of the example task was reportedly worked through entirely. This means the written two-part tutorial, the explanatory "how-to flip" video and even the optional video on flowcharts were evaluated and used to plan an own flip implementation.

All participants find the material to be well suitable for the requested implementation, partitioning of out-of-class and in-class work is found to be well thought and well laid out. Three of five participants reported that the use of the material fits more on higher grade levels (7th or 8th grade) in lower secondary and needs previous experience, ideally with physical contact to the micro:bit and initial input from a teacher. The three also found the material to stimulate independent, procedural thinking as well.

Previous experience and physical hands-on contact seem to play a key role when implementing this flipped design. This is addressed by the design of the workshop from the first-author in which previous in-class work with the micro:bit is emphasized. Physical learning takes place in the real world and is necessary for being able to abstract the functionalities later used in the virtual world [35]. It is expected to additionally burden the knowledge transfer process when introducing students to the flipped classroom concept. Therefore, the difficulty level of the "flipped" example should not increase further compared to the original example without ICM design. This has been reported unanimously to be fulfilled from the study.

The explanatory flip video and the optional flowchart video were rated as totally fitting by all participants. Three out of five participants perceived both videos as stimulating, diversifying, well explained, and supporting individual pace. Also, two out of five participants find that the flowchart video and the embedded question stops are well suited for teaching Basic Digital Education (BDE) even for teachers with weak background in CS and informatics. The heavily needed teachers for BDE in Austria can develop confidence and gain within CT when using the developed video material.

The two-part tutorial contains text and "spoiler" hyperlinks uncovering additional information with pictures and pictorials of the programming part. This central element of the study should force self-driven and student-centered learning. While not revealing everything immediately just-in-time information supporting the inquiry-based learner is provided. This fits also into the 5E model and the merging of inquiry-based learning with the flipped classroom [16]. All participants reported that they like the use and the way of implementing the "spoilers".

They see inquiry learning to be forced but at the same time the ability to use the uncovering function when needed as a guideline or check for correctness. Furthermore, three out of five participants find the material well suited for self-driven in-class work without previous experience – apart from ICM. Additionally, self-directed learning at one's own pace was also confirmed by two of five participants.

As expected, minor refinements using the feedback could already be integrated immediately into the material as follows. All participating teachers asked for a version without question stops [38] of the flowchart video – to use the video for repetition or when teaching programming in another context. Four of five participants reclaimed to change the text of the "spoiler" links from "hint" to "hint**S**" using the plural. This should make it clearer that for every single step a picture with a programming block is available – like in a photo gallery on the web with back and forth buttons for navigation. Although the tutorial provides a hyperlink to the original example task on another website, two of five participants asked to include a step zero (0) in the tutorial with a description of the initial situation of the redesigned example task for assignment. This description was only available in the explanatory "flip" video and could be easily implemented in the tutorial.

All five participants reported that they will use the material as provided with additional personal explanations in the beginning. They are very interested and willing to report back after personal implementation. Three of five participants stated to wait for the completion of the first implementation in their classes before changing anything in the material. The other two participants claimed changes that were be implemented ad-hoc as discussed before.

V. Conclusions

Dealing with unprepared students is the first important issue to tackle for a successful flipped learning design. In the context of ICM, "unprepared" students are those who show up for live in-class work without having completed the flipped pre-class assignment in self-study [39]. The example task "Reaction Time Meter" is also very suitable to demonstrate possible remediation against unpreparedness in practice. Its functionality for measuring the reaction time and the core concept of the programming part works exactly the same way and produces the same output, with or without extension of the example task. From a pedagogical point of view, this is an ideal starting point in the live teaching part, where the special treatment of unprepared students during remedial work has a somewhat stigmatizing effect. The effect can be further reinforced by spatial separation during the special treatment, which should create enough motivation to resolve the students' uncomfortable situation themselves.

The live class can be used as a pure handicraft lesson. Learners who have not completed the explanatory video including the assigned micro:bit task can enjoy a making lesson "unplugged". In an unplugged lesson the "current" is missing during the exercise, so to speak. This means everything that requires electricity is out of scope for those unprepared at first, except for video or other multimedia instructional content. The part of programming the micro:bit is temporally appended afterward instead of before in the flipped setting. If there is still enough time after completing pre-class work during the live lesson, programming can already be started but needs to be completed as homework.

The only disadvantage in this design is that the flipped version of the programming chosen here was deliberately set at a basic difficulty level. Therefore it will be possible for some students to catch up on the missing information during in-class work. On the other hand, if the flipped intermediate step of program 1 is completely omitted, the example will not work right away. It is expected to be too difficult to implement program 2 in one run of in-class work without the experience of program 1, which initial experience confirms. In the interest of the equal treatment of all students, it should be made clear that there is no advantage in skipping the flipped video including the assignment before the live class. The choice is therefore up to the students how to complete both programs pre-class and in-class. It is recommended to require the submission of both program versions for "flip" laggards with an extra teacher appointment. *Table I* contrasts the adapted learning design for "flip" laggards to the original "flip" planning.

Table I
Laggard learning design adaption

regular video usage *original 'flip' planning*	**deferred video usage** *partially overlapping phases for 'flip' laggards*
	~~1. pre-class flip: program 1 →before live~~ *(omitted by student)*
1. pre-class flip: program 1 →before live	2. in-class work: making + ~~program 2~~ program 1 →live
2. in-class work: making + program 2 →live teaching	3. homework: program 2 →later
	4. extra teacher appointment: merging of step 3 and 2 →completion

To be able to test program 2 (step 3 for laggards) with the aluminum pads constructed in the making part (step 2), an extra teacher appointment must be arranged in step 4 for laggards. Thus, learners who have to rework the flipped part experience the additional burden. However, the extra effort for teachers and learners soon pays off, because after only a few repetitions of the stated "laggard" procedure it becomes clear where and with whom the additional expenditure occurs in the long run. Especially more for the learners, if the flipped part is not completed upfront. This can also be seen as a kind of familiarization process for the flipped lessons and should be planned as such.

The presented study aimed to provide a practical guideline for flipping a textbook example task on computational thinking and the micro:bit and to further investigate the usability of this guideline. Not only in times of pandemic homeschooling the use of video recordings and other multimedia content for theory transfer is important and becomes more and more accepted. In education, the advancing of digitization helps teachers to outplace repeating and more static content from the classroom with the use of ICM. More quality-time for in-class work and individualized support of the learner is created. Additionally, the role of the teacher evolves towards a learning-coach who helps the student to design a custom learning solution, especially in the makerspace part. The combination of the haptic experience in makerspaces with pre-learned theory from video instructions consolidates the learned and creates new, action-relevant knowledge.

Splitting the example task into a programming part and a makerspace part for ICM is confirmed to be the right way to proceed and should be further investigated on a larger scale. The use of a makerspace part in an example task as a clear to determine element helps to create an appealing redesign and flip of the original example. If no makerspace activity is in the original example or the extension of it, there is a need to create one before a flip redesign can be started.

Ideally, this research paves the way to a future adaption and redesign of the entire textbook for flipped classroom delivery. This would help to strengthen the confidence of more teachers, especially those with a weak background in CS and informatics, to teach Basic Digital Education and broaden the use of CT in lower secondary schools in Austria.

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