A Research-Practice Partnership to Introduce Computer Science in Secondary School: Lessons from a Pilot Program

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Context Introducing Computer Science (CS) into formal education can be challenging, notably when considering the numerous stakeholders involved which include the students, teachers, schools, and policy makers. We believe these perspectives should be considered conjointly, which is possible within Research Practice Partnerships (RPPs). RPPs look to bridge research-practice gaps and have seen an increase in the field of education and CS-education. Unfortunately, RPPs are considered to be under-researched, in addition to presenting their own challenges.

Objectives To the purpose of assessing how RPPs may support the successful introduction of CS into formal education, we investigate three perspectives (students, teachers, and RPP stakeholders) and their interplay within the context of a multi-institution RPP conducting a pilot program to introduce CS to secondary school students.

Methods A mixed methods analysis was employed to triangulate data in a concurrent triangulation design. The data included i) 3 surveys distributed over the semester to 106 grade 9 students (ages 12-14), ii) four teacher-journals, iii) 2 interviews and 4 focus groups with the teachers and representatives of the partner institutions.

Findings From the *students' perspective*, while their self-efficacy increased, their motivation decreased throughout the semester due to a miss-match between their expectations and the course. The findings also indicate that gender biases and heterogeneity are already present in grade 9. From the *teachers' perspective*, co-constructing the study plan, having access to regular support and collaborating within a community of practice when starting to teach CS all facilitated the teachers' experience. Finally, from the *RPP's perspective* the collaboration between stakeholders and having researchers evaluate the program were considered to be key elements in the pilot program. However, there appears to be a research-practice gap, in big part due to limited interactions between researchers and curriculum designers, and researchers and the teachers in the field.

Conclusions From the *students' perspective* it appears relevant to introduce CS i) prior to secondary school to address motivation and bias-related issues early on, and ii) to all students to avoid participation being motivation-, stereotype-, or belief-driven, and risk broadening the gap between students, iii) all the while being attentive to course format and content to ensure that the course meets students' expectations and fosters autonomous motivation. From *the teachers' perspective*, while the provided support met the teachers' needs, it is essential to find means of scaling such approaches when looking

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to deploy CS-curricular reforms to entire administrative regions. Finally, from the *RPP's perspective* i) teachers' should be given a voice in the RPP to better align with the field, and ii) researchers' roles should be reconsidered to move beyond being only evaluators, and towards having a more co-constructive role in setting up the curricular reform. Recommendations are provided for researchers and practitioners involved in CS curricular reforms.

CCS Concepts: • **Social and professional topics → Computer science education**; **K-12 education**; **Adult education**.

Additional Key Words and Phrases: Computer Science Education, Secondary school, Teacher professional development, Formal learning environments, Curriculum development, Research practice partnership

1 INTRODUCTION

There is a growing consensus regarding the importance of introducing Computer Science (CS) into formal education. The introduction of CS for all is, however, not without its challenges [18] with numerous countries having struggled with the implementation of their CS curricular reforms (e.g. the UK [78] and France [67]). Their experiences and the literature highlight that the successful implementation and sustainability of CS reforms is dependent on multiple factors [54, 64] and the complex interactions between multiple levels and their stakeholders (students, teachers, classrooms, schools and districts to name the first) [43, 46, 77]. The stakeholders at these different levels must work together to support the successful implementation and sustainability of reforms [43, 46, 77]. In this article we focus on three levels known to significantly impact the success of the CS and therefore contribute to broadening participation in the field (students, teachers and the school and district level through research practice partnerships) and discuss solutions for the design of CS reforms that take into consideration the sustainability and scalability of the solutions proposed [14].

1.1 Students

At the *student-level*, given the lack of consensus on what should be taught in K-12 [29] and how [84, p.1], it is important that the curriculum design helps broaden participation in CS to all students, irrespective of existing stereotypes and biases around the discipline [50, 53]. One approach is to foster students' autonomous motivation [68] and self-efficacy [4], in light of the importance of these metrics for academic achievement in general [4, 41, 58], educational choices, and career decisions [6, 89]. According to self-determination theory [68], the impact on performance differs according to the type of motivation [41]. Indeed, students with high intrinsic motivation (i.e. intrinsic interest) and identified regulation (i.e. personal value) are likely to perform better than those with high introjected regulation (i.e. ego involvement) and external regulation (i.e. external incentives). *Self-efficacy* on the other hand is considered to have an impact on motivation [4, 92] as self-efficacy beliefs are considered to "determine the goals people set for themselves; how much effort they expend; how long they persevere in the face of difficulties; and their resilience to failures" [4]. Self-efficacy has indeed been found to impact people's decisions [6] and relate to academic achievement [58, 92]. It is thus essential in education generally and in CS-education specifically to successfully motivate students, promote their self-efficacy, and effectively move beyond stereotypes [53] and prior beliefs. Achieving such is highly dependent on the instruction received and thus requires accounting for the teachers.

1.2 Teachers

To achieve the objective of providing positive CS experiences which may affect the students' attitudes and improve their persistence in the field, teachers must be trained to teach CS, bringing us to the *teacher- and classroom-levels*. To that effect, adequate teacher professional development (PD) should be provided, over a sufficient amount of time, and with adequate feedback, to support teachers in the introduction of the new discipline and the subsequent changes to their practice [18, 21, 33]. Unfortunately, where CS is concerned, as stated in [26], there are several countries that have not provided teachers with CS-PD organised by the department of education. This is considered to be due to the difficulty of providing large scale PD-initiatives that follow teacher-PD best practices and provide adequate teacher-support which contribute to sustained changes in teachers' practices [78], all the while avoiding the issues related to top-down initiatives that are less likely "to promote local actors' motivation and ownership of the reform" [79]. Indeed, "top-down reforms tend to have a weak impact on the everyday life of schools because they often fail to enhance ownership over the reform and build aligned understanding of the reform across different levels of the educational system" [79]. By ensuring that teachers have a voice, this may help "overcom[e] resistance to innovations and [reduce] uncertainty" [22]. Furthermore, as sustaining changes in teachers' practices is one of the biggest challenges in education [43], the support must be adapted to the teachers' needs and persist beyond the PD-program itself. Therefore any solution within a curricular reform should consider the need for scalable and sustained support "at multiple levels within the system to support [teachers'] efforts" [14]. This support should therefore exist and persist within the schools [24] whether through the actions of school leaders [34, 57, 91], instructional coaches [14, 62, 73], or the teacher community itself with teachers engaging in a community of practice [13, 24, 46].

To further add to the complexity of the required teacher-PD, there are two related issues that arise from limited interactions between developers of computing education curricula, and researchers, with teachers:

- there are known discrepancies between what is intended by the curriculum, what is taught by teachers (enacted curriculum) [27] and what students learn [82];
- it would appear that evidence-informed Computing Education best practices are not globally implemented in schools [55, 72], which is coherent with the well known research-practice gap which exists in numerous fields [8, 17, 20, 28], despite the fact that educators may be interested to use research outcomes to inform their practice [28].

1.3 Research practice partnerships that include all stakeholders

One way of ensuring that the aforementioned best practices are implemented in the field, and which has been gaining in interest in recent years in the field of education [15] and CS-education [54], are Research-Practice Partnerships (RPPs), *bringing us to the school- and district-levels*. RPPs attempt to bridge the research-practice gaps [15] which exist "as researchers might not focus on issues relevant to practice" and "practitioners might not have the time or resources to use research knowledge" [75], a sentiment echoed in the context of CS education [55]. RPPs thus bring together researchers and practitioners in the field "to investigate problems of practice and solutions for improving schools and school districts" [15] with the objective of enabling "a greater use of research in decision making, address persistent problems of practice, and improve educational outcomes" [15]. However, as stated by Sjölund et al. [75] in their systematic review on the use of research to inform practice through RPPs: "little is known on how research is and/or can be used in RPPs" in the context of teacher professional development.

There are numerous ways research may be used that will have a direct impact on the process and outcomes of the partnership [75]. For instance, Adrion et al. [2] found that the partnership was "most successful when research addresse[d] real problems of practice and when the outcomes influence[d] teacher, school, and district actions and policies". The fields of applications of RPP are also vast, with many of the interventions leading to positive outcomes, and advocates arguing that the solutions emerging from RPPs may be more sustainable and scalable [15]. However, as stated by Coburn and Penuel [15], "most research on the outcomes of RPPs in education and other fields has focused on the impact of interventions developed in the context of a partnership. Thus, they do not investigate the impact of the partnership itself or other outcomes of RPPs". While there are certain recollections written by researchers to provide insight into how RPPs worked, they are not a systematic study "on perspectives and experiences of the full range of participants". Nonetheless, there appear to be certain consistent challenges [15, 54, 55, 75] in the implementation of RPPs such as defining roles [74] and responsibilities, managing divergent expectations, power imbalances, building trust, sharing knowledge (for instance due to lacking a common language), and engaging all practitioners in the research process to produce relevant research for practice. Finally, it is important in such a context that teachers have an active role in the partnership, as well as interact with researchers in order to positively affect teacher self-efficacy, sense of ownership, expand their professional network, and change classroom practices to name a few examples [25, 55]. Such partnerships also benefits the researchers who "are able to gain a deeper understanding of school contexts, including policies and procedures" as well as "an increased confidence in the value of their work" [55].

1.4 Problem Statement and Research Questions

To the best of our knowledge, most curricular reforms and PD programs focus on evaluating the teachers' perspective, with many lacking insight into the student-level outcomes despite being a key outcome metric [36]. Furthermore, few in the context of CS-Education curricular reforms take advantage of RPPs and even less simultaneously consider how the experience is impacted by the RPP, and more specifically, the researchers' role and interaction with the other stakeholders. We believe that these three perspectives (students, teachers and RPP stakeholders) should be considered simultaneously when evaluating a curricular reform: only by understanding their impact on the success of the endeavour, and how they interplay, is it possible to propose solutions which increase the likelihood of success of the reform. In the present article, we thus investigate these three perspectives simultaneously within the context of an RPP looking to introduce CS in grade 9 (ages 12-14) and consider the following research questions:

RQ1: Does the proposed CS curriculum format and content promote students' self-efficacy and autonomous motivation?
RQ2: Does the CS-curricular reform pilot program provide teachers adequate support to teach CS?
RQ3: Does the RPP contribute to the CS-curricular reform and what challenges arise as a result of this approach?

As the purpose of RPPs is to address the issues that practitioners face in the field [15], the present study looks to advance our knowledge on RPPs and contribute to the literature by showing how some challenges may arise in different contexts, and more importantly, how they may be addressed in light of the need to create a sustainable and scalable CS curricular reform. Therefore, based on the findings, recommendations were co-constructed with teachers and representatives of partner institutions, and are provided for stakeholders involved in CS-curricular reforms and related RPPs in section 4. The recommendations are anchored in the literature, and account for the sustainability and scalability [14] of such solutions.

2 METHODOLOGY

2.1 Context : An RPP to co-construct the CS curricular reform

The study took place within the EduNum project which aims to introduce CS to all K-12 students in Canton Vaud, Switzerland. This project leverages a multi-institution RPP to pilot CS-curricular reforms for all levels of schooling prior to large scale deployment [26]. The RPP is a hybrid between a *Design / CoDesign* model which uses "a collaborative model of designing, studying, improving, and then scaling class practices based on empirical evidence" [54] and a *Research Alliance* where "researchers and leaders work together in an iterative process [to] identif[y] challenges, test strategies, and fin[d] solutions over the long term" [54]. The RPP's objective was to pilot the secondary school (9th grade, ages 12-14) CS-curricular reform in spring 2021 for a first cohort of students without prior CS experience. The pilot included :

- three voluntary schools : an urban primary and secondary school with approximately 1200 students (A), a rural primary and secondary school with approximately 1050 students (B). and an urban primary and secondary school with approximately 1350 students (C),
- representatives from four partner institutions involved in the CS-curricular reform (the university of teacher education, technical university, local university and department of education) [26].

Although the grade 9-11 curricular objectives and study plan had been defined in 2018 these had to be adapted in the context of the pilot program to account for several constraints. The first is that this pilot was the first iteration of the CS curriculum for grades 9, and the objective was to give the students an overview of the full range of topics they would have seen throughout grades 9-11. Therefore, rather than opting for a study plan that involved a detailed exploration of each of the CS subtopics, as should have been the case over a three-year period, a few multi-week activities supposed to be representative of those subtopics were selected. The second is that the students had no prior formal mandatory CS instruction, due to piloting and deployment timeline of the curricular reform. Therefore the study plan had to be adapted to account for the fact that students had no prior knowledge. To adapt the plan, the representatives drew inspiration from the primary school curriculum also established by the RPP in 2018 for grades 1-4 and piloted over the course of the 2019-2020 academic year [26] [1]. The resulting curriculum and PD-program for grade 9 thus covers the following CS dimensions which are based on Schiper [70]'s decomposition of CS and detail the corresponding subtopics:

- Algorithms and programming : algorithms, languages, programs, instructions, sequences, loops, conditions, bugs, tests
- Machines and networks : executing instructions, combining instructions for complex tasks, robots as machines that interact with the environment (sensors, effectors, central processing unit), networks (addresses, messages, sender, receiver)
- Information and data: data storage and processing, images and pixels, text represented as numbers
- Impact of CS on society

Given these objectives, the initial study plan was proposed by the experts in the university of teacher education in collaboration with the coordinator from the technical university (see section 2.2.1) while the recruitment of teachers was underway (see section 2.2.3). The specific weekly objectives were then refined with the teachers who volunteered and were selected to teach the course throughout the semester to adjust with respect to their needs and experience (see section 2.2.3). The roles and interactions between the different stakeholders within the RPP and throughout the pilot program are detailed in the following sections. An interaction timeline is provided in Table 1.

2.2 Participants, their roles and interactions in the RPP

2.2.1 Representatives of the partner institutions. Fifteen members of the partner institutions involved in the curricular reform volunteered to participate in the pilot project:

- 3 directors (one per school) who volunteered to have their schools participate in the pilot program. One of these school directors was also the director of the Digital Education curricular reform project at the level of the department of education
- 3 instructional coaches (one per school), who were in charge of providing support within the schools and provided contextual knowledge from the field to adapt the pilot program. These instructional coaches

[1] The grade 1-4 curriculum was co-constructed by the RPP and included members of the four partner institutions who had hired teachers to join the technical university as pedagogical and didactic experts, as well as experts in Computer Science. During the piloting phase a first cohort of instructional coaches pre-tested the PD program and pedagogical content to provide feedback for adjustment prior to the full cohort of teachers who also gave feedback that helped adjust prior to deployment.

Table 1. Interaction timeline to set up the CS-pilot program

Date	Event
July 2020	Decision by the department of education to do a small-scale pilot for CS, ICT and digital citizenship facets of the wider Digital Education curricular reform in grade 9
August 2020	Call for schools to participate in the pilot & recruiting the representatives of the partner institutions who would engage in the pilot
September 2020	Discussions regarding the pilot program's objectives involving the department of education, schools and representatives of the partner institutions, namely who would be involved in piloting the three dimensions of Digital Education
October 2020	Validation of the objective and beginning to set up the specific CS pilot program
October 2020 - January 2021	Teacher recruitment for the CS pilot program
November 2020	Visits to the schools by project coordinators to meet the directors and instructional coaches
	Communication to parents so that students may volunteer to participate in the program
December 2020 - January 2021	Preparation of the first draft of the 6 month study plan for CS in grade 9 based on the curriculum that was validated in 2018
	Visit to the schools by the teachers to promote the optional CS course prior to the launch of the pilot program
January 2021	Start of the teachers' meetings with the professor of the university of teacher education (once every two weeks)
	First student survey conception with project coordinators and trainers
February 2021	Start of the pilot program and the weekly CS lectures.
	First student survey administration by teachers
	First student survey feedback by researchers to all stakeholders
March 2021	Second student survey conception with the project coordinator, professor from the university of teacher education, with feedback from teachers
April 2021	Second student survey administration by teachers
May 2021	Second student survey feedback by researchers to stakeholders, including a session organised only for teachers, and one with all the stakeholders
	Third student survey conception with the project coordinator, professor from the university of teacher education, with feedback from teachers
June 2021	Third student survey administration
July 2021	Interviews with the project coordinators, professor of the university of teacher education and teachers
	Report of the results of the pilot program for all stakeholders in the RPP and the broader curricular reform project

had participated in a professional development program to train them to support their colleagues in the introduction of the discipline.

- 3 members of the department of education, one of whom was in charge of coordinating the grades 9-11 digital education curricular reform
- 2 members from the university of teacher education with expertise in teacher professional development and CS. One of them, a professor with a PhD in computer science, was training future high school CS teachers and had contributed to the elaboration of the CS study plan for primary and secondary school. They were also in direct contact with the four teachers (see section 2.2.3) who taught the CS course.

- 1 member from the technical university, a project coordinator, an ex-teacher with expertise in learning sciences, and the coordination of a school-wide ICT reform
- 1 member of the local university

These representatives, considered to be experts in their fields, i) co-constructed the study plan while the teachers were being recruited, and proposed the study plan to the teachers at the start of the pilot, and ii) provided insight throughout the program considering the constraints of future large scale implementation.

2.2.2 Researchers. Within the RPP, two researchers from the technical university contributed to the pilot program. Their role was to evaluate the pilot program (see section 2.3) to validate the practice and inform the decision making (instrumental use) [75] by proposing evidence-informed recommendations (see section 4) in relation to the results. The interactions were conducted in multiple phases:

(1) The researchers and practitioners acted as co-inquirers of the effectiveness of the pilot program, meaning that the researchers and practitioners collaborated here on defining the aims and methods [74]. More specifically, the pilot program evaluation was established between the researchers, the professor from the university of teacher education and the project coordinator from the technical university (see section 2.3), before being submitted for validation by the representatives of the different institutions.
(2) The researchers then analysed and synthesised the data for the pilot program evaluation.
(3) The researchers then acted as design advisors and the practitioners as design validators [74] for the recommendations for future iterations of the pilot program. This means that after the initial co-design phase, the researchers provided recommendations for practice which the practitioners had to validate. More specifically, this entailed discussing the results and their implications, including recommendations based on the literature, with the two research co-designers from step (1) and the teachers (see section 2.2.3). The results and proposed recommendations were then discussed and validated with the representatives of the different institutions in light of future piloting phases and large scale deployment (see section 2.3.3).

While the researchers did not inform the initial curriculum design, the objective was to have concurrent research to inform the future iterations of the project, and that the discussions help practitioners inform researchers of the feasibility of the proposed solutions in the field.

2.2.3 Teachers. To teach the pilot program CS-course, the stakeholders looked to teachers enrolled in the University of Teacher Education's to obtain a CS teaching diploma for lower secondary schools (grades 9-11). These teachers had at least 40 prior CS-related credits according to the European Credit Transfer and Accumulation System (ECTS), and prior classroom experience to ensure that the teachers had some level of pedagogical content knowledge. This PD program included i) a theoretical module in CS-didactics (12 ECTS), a practical CS-related internship (7 ECTS), and an integration seminar to link the theoretical and practical modules (2 ECTS). Following a call to teachers enrolled in this program, four pre-service teachers (two men and two women) volunteered and were selected to teach an ungraded weekly 45-minute CS lesson for grade 9 students (ages 12-14) as part of their mandatory internship:

- One teacher was in their first year of the CS teaching program for lower secondary school at the University of Teacher Education and had previous experience teaching CS and programming at a college.
- One teacher already had a teaching diploma and was teaching mathematics to grades 9-11 and enrolled at University of Teacher education to acquire the CS teaching diploma for lower secondary school.
- One teacher was completing their basic training to teach in grades 9-11, and was already familiar with grades 9-11 classes, having been a substitute teacher in science and mathematics in these grades for several years.

Table 2. CS course content, format, and student data collection timeline. S1: initial survey 1, S2: student survey, S3: final survey.

Week	Course theme	Content (topic addressed)	Format (pedagogical activities used)	Data
1-2	Algorithms and Programming	Instructions, sequences	code.org or Scratch [65] activities	S1
3-4		Loops	code.org or Scratch [65] activities	
5-6		Conditional statements, functions	code.org or Scratch [65] activities	
7-8		Issues at stake: AI	Classroom discussion	
9-10	Information	Binary: numbers, images, pixels	Unplugged activities	S2
11-12		Issues at stake: Data, profiling, cookies and metadata	Discussion and an escape game	
13	Machines and Networks	Issues at stake: networks and routing, discussion on digital tracing	Unplugged activities	
14		Robotics: sensors and pre-programmed behaviours	Unplugged activities with the Thymio II robot [66]	
15-16		Robotics: block based programming	Programming the Thymio II robot [66]	
17		Issues at stake: social networks	Unplugged activity and discussion	S3

Table 3. Number of students participating in the lectures and data collection. Abbreviations - B: boys, G: girls, U:unknown (not disclosed), S: survey

School	Classes	Survey 1 Respondents				Survey 2 Respondents				Survey 3 Respondents			
		Total	B	G	U	Total	B	G	U	Total	B	G	U
A	3	45	25	18	2	33	19	11	3	15	10	4	1
B	2	23	16	7	0	21	13	8	0	16	11	4	1
C	3	31	18	12	1	28	14	11	3	28	14	9	5
Not disclosed		8	2	3	3	10	5	1	4				
Total	8	107	61	40	6	92	51	31	10	59	35	17	7

- One teacher was already a full teacher for mathematics and a substitute teacher for CS for several years in grades 9-11. Although he did not have a CS teaching diploma at the time, he was in the process of acquiring it at the start of the pilot program.

The lectures took place between the 1st of February and the 2nd of July 2021 (i.e. 15-17 weeks). As part of the ongoing PD support, the four teachers met as a group with a professor from the University of Teacher education every two weeks (and more if required). During these sessions they debriefed on their classroom experience, got feedback and answers to their questions, and created / adjusted upcoming lessons. The resulting study plan, with a description of the content (subject taught) and format (i.e. type of activities employed) can be seen Table 2).

2.2.4 Students. In total, 107 9th grade students from 3 schools (see Table 3) volunteered to participate in one CS lesson per week for 15-17 weeks. These students had no prior formal CS-education courses as these were only introduced in grades 1-4 in 2018-2019, grades 5-6 in 2019-2020 and grades 7-8 in 2020-2021 in parallel with the grade 9 pilot program that took place in Spring 2021. Parental and student consent was obtained for the study, with students being able to opt out at any point in time.

2.3 Data collection and analysis

The analysis employed a mixed methods approach in a *concurrent triangulation design* where the quantitative and qualitative data were collected at the same time, analysed separately, and their results compared in order to draw the final conclusions. The data included 3 student surveys (see section 2.3.1), 4 teacher journals (see section 2.3.2), 2 interviews and 4 focus groups with teachers and institutional representatives (see section 2.3.3). Please note that key quotes from the qualitative data are presented in coloured boxes throughout article.

2.3.1 Student surveys. Three surveys (see Table 4) were administered (at the start, mid-point and end of the course, see timeline in Table 2) to evaluate the program from the students' perspective. The first survey establishes a baseline of the students' perception of the discipline. The second and third surveys gave the students the opportunity to express their opinion regarding the course, in terms of format and content. In all surveys we assessed students' *autonomous motivation* [68] and *self-efficacy* [4] in light of the importance of these metrics for academic achievement in general [4, 41, 58], educational choices, and career decisions [6, 89]. Autonomous motivation refers to a person choosing to engage in an activity because they are intrinsically (i.e. interested), rather than extrinsically motivated (i.e. feeling forced) motivated by doing the activity. This can be measured on a continuum ranging from being interested, finding it useful, not being motivated, wanting to prove to others they can do it, and being forced to do it [32]. According to self-determination theory [68], the impact of motivation on performance differs according to the type of motivation [41]. For example, students with high intrinsic motivation (IM, i.e. intrinsic interest) and identified regulation (IdR, i.e. personal value) are likely to perform better than those with high introjected regulation (InR, i.e. ego involvement) and external regulation (ER, i.e. external incentives). Researchers have therefore proposed to measure autonomous motivation through multiple sub-scales (e.g. using self-regulation questionnaires [32] or the Situation Motivation Scale, SIMS, [35], see Table 4) . These surveys cover each of the autonomous motivation dimensions and combines them into a single autonomous motivation variable through the Relative Autonomy Index [32] that constructs a global autonomous motivation (AM) score. As explained by Howard et al. [42], this is achieved by combining motivation sub-scores (i.e. the answers to the 5-point Likert questions for each type of motivation) as shown in equation 1. The lower the index, the less autonomously motivated the student is to participate in the CS-course (and therefore the less interested and the more forced they feel). The higher the index, the more autonomously motivated the student is to participate in the CS-course.

$$AM = (2 \times IM + 1 \times IdR - 1 \times InR - 2 \times ER)/6 \quad (1)$$

The data collected through the three surveys (see Tables 2 and 4) were analysed through *descriptive and inferential analyses*. The inferential analyses considered the following independent variables: i) *Gender* as CS-related stereotypes and gender gaps [53] exist starting an early age; ii) the *school* that the students attended as socio-cultural factors [60, 89], and school culture [4, 52] as this may impact self-efficacy and motivation; and iii) *curricular orientation* (vocational or general) which is often associated with differences in aptitudes in the Swiss educational program[2]. Analyses of variance (ANOVA) were employed to establish significant differences between these groups, while controlling for the normality of the residues. Dunn's test for pairwise multiple comparisons of independent groups was employed if the ANOVA was significant. Benjamini-Hochberg p-value correction for multiple comparisons was applied to decrease the false discovery rate. Reported statistics also account for the minimum effect size (Cohen's D) required to meet a statistical power of 0.8 with a significance level of $\alpha = 5\%$.

[2]Students in the vocational orientation (~ 70% of students) pursue their upper secondary education in vocational schools, while those in the general orientation (~ 30% of students) go into senior high school.

Table 4. Student survey questions. All questions are on a 5-Point Likert scale. Autonomous motivation questions are based on the Situational Motivation Scale (SIMS8) [3] and the Motivation At Work Scale [31]). Self-efficacy questions draw inspiration from the Motivated Strategies for Learning Questionnaire [63]). The questions on development of transversal skills are based on the curriculum (see plandetudes.ch/capacites-transversales). Cronbach's α is provided for the scales as evidence of reliability. Please note that the items are translated from French.

Theme	Concept	Question	Survey		
			S1	S2	S3
Autonomous motivation [3, 31] (Cronbach's $\alpha_{all} = 0.83$, $\alpha_{S1} = 0.78$, $\alpha_{S2} = 0.78$, $\alpha_{S3} = 0.85$ with reverse coding of InR and ER items)	Identified regulation (IdR)	I think this course will be / is / was useful for me	x	x	x
	Intrinsic Motivation (IM)	I think this course will be / is / was interesting	x	x	x
	Identified regulation (IdR)	I think this course will be useful for my future studies	x	x	x
	Identified regulation (IdR)	I think this course will / is / has brought me something	x	x	x
	Intrinsic Motivation (IM)	I think I will / am / have enjoyed this course	x	x	x
	Intention	I would like to do other courses like this one		x	x
	External Regulation (ER)	I will / have invested myself because I don't have a choice	x	x	x
	Introjected Regulation (InR)	I will / have invested myself because I want to make a good impression	x	x	x
	External Regulation (ER)	I will / have invested myself because I have to do it	x	x	x
	Introjected Regulation (InR)	I will / have invested myself because I want people to think I am competent	x	x	x
	Intrinsic Motivation (IM)	I will / have invested myself because the subjects proposed interest me	x	x	x
Self-efficacy [63] (Cronbach's $\alpha_{all} = 0.79$, $\alpha_{S1} = 0.83$, $\alpha_{S2} = 0.75$, $\alpha_{S3} = 0.81$)	Perceived course capacity	I think I will / am / have succeeded to follow this course	x	x	x
	Perceived course capacity	I think I will / am / have managed to follow this course	x	x	x
	Perceived course competency	I feel / felt competent when following this course		x	x
Development of transversal skills (Cronbach's $\alpha_{all} = 0.88$, $\alpha_{S1} = 0.77$, $\alpha_{S2} = 0.86$, $\alpha_{S3} = 0.86$)	Critical thinking	I would like to / have discovered other facets of CS	x	x	x
	Critical thinking	I would like to / have developed my own ideas on the subjects taught	x	x	x
	Social issues	I would like to be / have become aware of the social issues related to CS	x	x	x
	Creative thinking	I would like to / have worked from my own initiatives	x	x	x
	Communication	I would like to / have expressed my ideas	x	x	x
	Collaboration	I would like to / have collaborated with other students	x	x	x
	Problem solving	I would like to / have solved problems	x	x	x
	Learning Skills	I would like to / have improved my learning skills	x	x	x
	Using maths	I would like to / have used my maths knowledge	x	x	x
Course evaluation (Cronbach's $\alpha_{all} = 0.75$, $\alpha_{S2} = 0.66$, $\alpha_{S3} = 0.84$)	Clear objectives	The objectives were clear		x	x
	Easy instructions	The instructions were easy to follow		x	x
	Structure	The course was well structured		x	x
	Rhythm	I was able to progress at my own pace		x	x
	Satisfaction	I am satisfied with what I have learned during the course		x	x
Demographic variables	Gender	I am : a boy / a girl / I do not want to say	x	x	x
	Perceived CS competency	How do you consider your CS competencies today : Not very competent, a bit competent, competent, very competent, expert	x	x	x

2.3.2 Teacher journals. As part of the pre-service teachers' training, the teachers were required to maintain a journal and document their observations, questions and recommendations for the course. These served two purposes. First, the professor accompanying the teachers would answer their queries and alleviate concerns throughout the semester. Second, the entries were coded to classify the types of difficulties the teachers encountered throughout the semester and used to complement the results of the surveys (section 2.3.1) and the teacher focus groups (section 2.3.3)

2.3.3 Interviews and Focus Groups.

Unstructured focus groups with all stakeholders on the student results. To ensure that all practitioners had access to the findings, a presentation and discussion of one hour was organised following each student survey. The objective was to inform teachers and representatives of the partner institutions of the pilot program's progress, present research findings, and validate ensuing recommendations. During these presentations, which were led by the researchers, unstructured focus groups were employed to obtain the stakeholders' perception of the results. This was completed in two stages: first with the teachers to provide them with the opportunity to express themselves without fear of judgement by their superiors, then with the representatives of the different institutions. The objective was to:

(1) Complement the findings with insight from the field, as provided by the teachers;
(2) Gain insight from stakeholders with years of experience in education, school management, teacher training, CS and curricular reform;
(3) Propose adjustments throughout the semester based on the obtained results, considering the constraints of the field.

Notes were taken during the focus groups and directly associated to the findings the stakeholders were commenting on (inductive approach). The stakeholders could see the notes being taken, thus exposing the researchers' reflective process, and propose corrections and minimise misinterpretations [61]. By co-constructing these individual realities in a safe and exposed way, we obtained a fuller picture of the participants' perspective, thereby validating the researchers' interpretation which may be biased by prior experience [56].

Semi-structured interviews and focus group on the RPP experience. To reflect on their experience in the RPP, the four teachers were invited to participate in a 2 hour focus group, while the professor from the university of teacher education and the project coordinator from the technical university (who worked on the curriculum and PD design) participated in individual 1 hour interviews. The focus group and interviews followed a semi-structured interview guide that was organised in four distinct parts.

The opening questions (1) explored the interviewees' experience in the pilot program.

The second part of the interview (2) expanded on their experience co-constructing the program with the representatives they expressed having collaborated with, and how they believed it supported or did not support their work. For teachers in particular, the objective was to understand whether the type of support provided in the pilot was adequate. This is important because the curricular reform project in which this pilot project was conducted opted for instructional coaches as the main source of teacher support in grades 1-8. These instructional coaches are in charge of ensuring that the curricular reform persists in the long term in teachers' practices. This is achieved through a wide range of actions which can go from teaching the activities themselves in the classroom and co-teaching, to providing additional PD and efforts to help sustain a community of practice among the teachers [10]. There is however a shift in paradigm when moving to grade 9 as the teachers become specialists that teach a restricted set of topics. It is therefore important to understand the type of support that specialist teachers require so that the instructional coaches themselves may be trained accordingly in the subsequent piloting and deployment phases of the CS-curricular reform. Therefore, the first step is understanding what type of support these teachers need and whether what they obtained was adequate, before we can determine what exactly should be scaled and sustained.

The third part of the interview (3) explored the specific benefits of co-constructing with representatives of the different institutions involved in the curricular reform and the means of improving co-construction.

The final part of the interview (4) looked to co-construct a synthesis of the main takeaways.

The questions corresponding to the different interview parts are:

(1) Can you tell me a bit about your experience in the pilot?
(2) Who did you collaborate with? On what? How? Did the collaboration with them support your work?
(3) What were the benefits / facilitators and difficulties / barriers you experienced in the project?
(4) What are the main takeaways from your experience?

In an initial inductive approach to identify the main themes, the interviewer filled in a hidden synthesis table while the interviewees discussed their experience. The synthesis table recapped the main themes according to :

- the main people the interviewees interacted with
- whether the statements corresponded to benefits and facilitating elements versus difficulties and barriers

When the interviewees finished providing their takeaways, they were shown the synthesis table, which they finished completing with the interviewer to ensure that the themes were complete and provided an adequate representation of their experience with respect to all the stakeholders. This therefore provided a first thematic classification of the takeaways, in a transparent approach which helped validate the constructed picture and minimises misinterpretations [56, 61].

In a second inductive phase, two researchers observed the generated items from the synthesis tables and the interview transcripts[3] separately to create a map of coded themes (i.e. a thematic map which provides the themes and associated codes, see Table 5). Inter-rater agreement was established here based on the two researchers' agreement on the themes, their classification according to the project phase, the stakeholder the themes related to, and the candidate codes, rather than the coded transcripts themselves [19, p.264], due to resources and time available in the project for coding. The transcripts were then coded in two stages. First a descriptive coding approach was used to identify each passage's topic [69] drawing from the themes in the synthesis tables. This was followed by a focused coding approach [69] to identify categories in the data corpus for each of the themes and project phase. Once the corresponding quotes were identified, the conclusions were constructed over the course of several meetings between the two researchers to address any and all disagreements on the conclusions that were drawn.

The themes that emerged are structured according to the piloting timeline in which they occur (e.g. objective definition, preparation, implementation, analysis) and the candidate codes and can be seen in Table 5.

[3]The following number of words were transcribed for the main interviews 1430 with the coordinator (1h10 minutes), 2180 with the professor (1h26min) , 2100 with the four teachers (1h57)

Table 5. Qualitative data analysis themes and codes. Abbreviations - CRD: coordinators, TRN: trainers, TCH: teachers, STD: students, RCH: researchers

Project phase	**Themes (and codes)**	**Related to**				
		CRD	**TRN**	**TCH**	**STD**	**RCH**
Defining objectives	Global RPP interactions (collaboration, scale, vision alignment, organisation, time, balance)	x	x			x
	Researcher-practitioner interactions (links with research, state of the art, guidance, vision, time, communication)	x				x
	Practitioner-teacher interactions (teaching experience, prior testing, credibility, relationship, constraints, horizontal relationship)		x	x		
Preparation	Curriculum co-construction (creation, initial structure, adjustments, flexibility, interactions)		x	x		
	Community of practice (exchanging, preparing, collaborating, interacting with teachers to support each other)		x	x		
	Researcher-teacher interactions (communicating, explaining, vulgarising, presenting, objectives, adjusting methodology, adequacy)			x		x
Implementation	PD support (interacting with the PD provider, availability, necessity of the interactions, long term accompaniment, time, scalability)		x	x		
	Student engagement (motivation, satisfaction, curiosity, participation, expectations, prior knowledge, optional course)			x	x	
	Pedagogical difficulties (classroom management, logistics, heterogeneity, time)			x	x	
Analysis	Researcher-practitioner interactions for evidence based results (feedback, results, details, evolution, beliefs)	x	x	x	x	x

3 RESULTS

3.1 Students and the curriculum

3.1.1 Student self-efficacy, and the presence of gender biases and differences between schools. At the start of the program, the students did not consider themselves to be very competent in CS (see Fig. 1-S1). They were however confident that they could succeed in the course (see Fig. 2-S1). Already at this stage, a gender gap appears with boys feeling more competent ($F(1) = 21.9$, $p < .0001$, Cohen's $D = 1.0$, $\Delta = 0.9$ pts) and having higher self-efficacy ($F(1) = 11.6$, $p = 0.0018$, Cohen's $D = 0.698$, $\Delta = 0.505$ pts) than girls. Over time, the students remained confident in their capacity to succeed in the course ($F(2) = 0.01$, $p = 0.99$, see Fig. 2) and their perceived CS competency increased ($F(2) = 9.7$, $p = 0.00022$, Cohen's $D_{S_1 S_3} = 0.732$, $\Delta_{S_1 S_3} = 0.732$). While a gender difference persists at the end of the course for perceived CS competencies ($F(1) = 10.7$, $p = 0.0036$, Cohen's $D = 1.0$, $\Delta = 1.1$ pts), this is not the case with respect to their perception of being able to succeed in a CS course ($F(1) = 2.34$, $p = 0.19$). Similarly, while there were differences between schools in terms of perceived CS competence at the start of the course ($F(2) = 5.24$, $p = 0.028$), this is no longer the case at the end of the course ($F(2) = 0.95$, $p = 0.46$). While participating in the course appears to help bridge certain self-efficacy related gaps (either due to students progressing during the course, or having a better understanding of what the discipline entails, or a combination of both), it is important to stay attentive to remaining gender biases, even in cases where students voluntarily participate in CS courses.

3.1.2 Student motivation, and its decrease during the course. The first survey established that students were mostly Autonomously Motivated to follow the course (see Fig 3), which is coherent with their voluntary participation

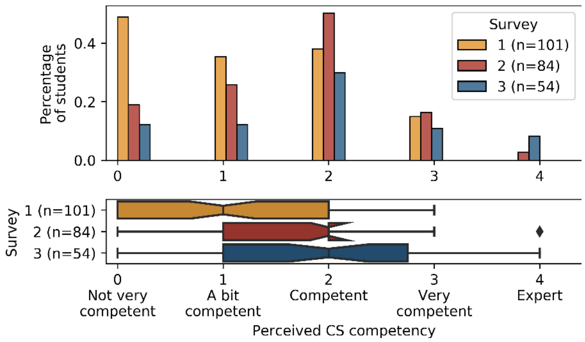

Fig. 1. Students' perceived CS competency

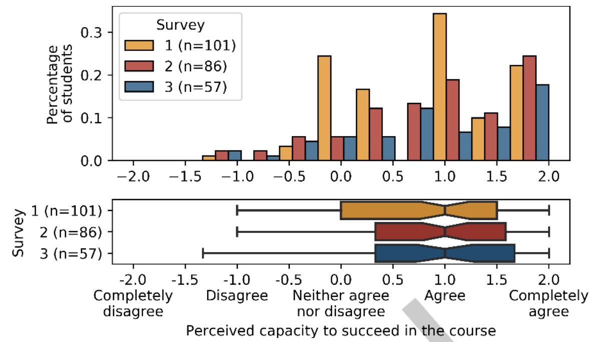

Fig. 2. Students' capacity to succeed in the course

in the pilot. The students are generally interested in CS (intrinsic motivation), believe it is useful (identified regulation), are not taking the course to make a good impression (introjected regulation) or feel forced to do so (external regulation). Students' autonomous motivation however depends on multiple factors. Boys are more intrinsically motivated ($F(1) = 5.43$, $p = 0.033$, Cohen's $D = 0.316$, $\Delta = 0.352$pts) and there are differences between schools in terms of intrinsic motivation ($F(2) = 4.56$, $p = 0.040$) and external regulation ($F(2) = 8.68$, $p = 0.0042$). Finally, differences are observed between curricular orientations. Students in the general orientation (who will later gain access to universities) exhibited a higher identified regulation than those in vocational orientation (who will train for a specific occupation).

Subsequent surveys showed that motivation rapidly decreases ($p_{S1_{S2}} < 0.0001$, Cohen's $D_{S1_{S2}} = 0.88$, $\Delta_{S1_{S2}} = 0.636$pts; $p_{S1_{S3}} = 0.0005$, Cohen's $D_{S1_{S3}} = 0.714$, $\Delta_{S1_{S3}} = 0.575$pts, n.s. S2-S3 difference), in particular due to a drop in identified regulation (i.e. perceived utility, $p_{S1_{S2}} < 0.0001$, Cohen's $D_{S1_{S2}} = 1.535$, $\Delta_{S1_{S2}} = 1.407$pts; $p_{S1_{S3}} < 0.0001$, Cohen's $D_{S1_{S3}} = 1.471$, $\Delta_{S1_{S3}} = 1.432$pts, n.s. S2-S3 difference) and intrinsic motivation (i.e. interest, $p_{S1_{S2}} < 0.0001$, Cohen's $D_{S1_{S2}} = 1.164$, $\Delta_{S1_{S2}} = 1.099$pts; $p_{S1_{S3}} < 0.0001$, Cohen's $D_{S1_{S3}} = 1.195$, $\Delta_{S1_{S3}} = 1.191$pts, n.s. S2-S3 difference). This drop is investigated in section 3.1.3.

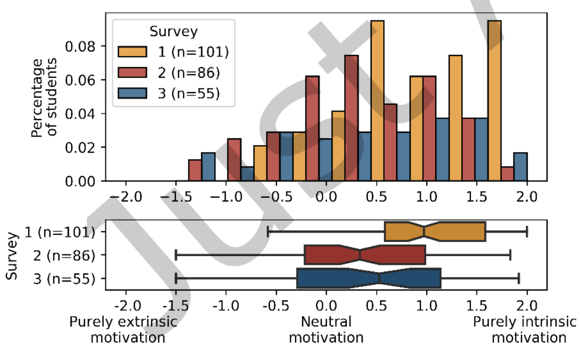

Fig. 3. Students' autonomous motivation

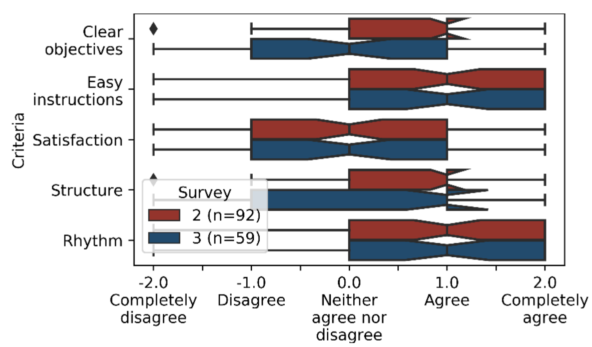

Fig. 4. Course evaluation criteria

3.1.3 *Course evaluation, and the mismatch between students' expectations and the course content.*

A positive course evaluation but decreasing satisfaction. The course is globally positively evaluated according to the criteria established in Table 4 (see Fig. 4 and 5). However, the students' satisfaction with the course is mitigated. Fig. 4 shows that the median satisfaction is at the midpoint, with as many students expressing positive and negative opinions about the course (28 positives and 34 negatives out of 87 in S2; 20 positives and 23 negatives, out of 55 in S3), independently of Gender ($F_{S2}(1) = 1.8$, $p_{S2} = 0.33$; $F_{S3}(1) = 0.26$, $p_{S3} = 0.66$). There is however an effect of the schools ($F_{S2}(1) = 1.67$, $p_{S2} = 0.33$; $F_{S3}(1) = 9.0$, $p_{S3} = 0.0017$) and curricular orientations ($F_{S2}(1) = 2.1$, $p_{S2} = 0.29$; $F_{S3}(1) = 10.6$, $p_{S3} = 0.005$) on the students' satisfaction. A correlation analysis using Spearman's ρ showed that the most satisfied students are also the most intrinsically motivated to follow the course ($\rho_{S2} = 0.7$, $p < 0.0001$; $\rho_{S3} = 0.84$, $p < 0.0001$). They have higher identified regulation ($\rho_{S2} = 0.76$, $p < 0.0001$; $\rho_{S3} = 0.79$, $p < 0.0001$), and believe they have developed more transversal competencies ($\rho_{S2} = 0.58$, $p < 0.0001$; $\rho_{S3} = 0.72$, $p < 0.0001$).

A drop in motivation due to the mismatch between the course and students' expectations. It would indeed appear that we are below students' expectations when it comes to developing transversal competencies ($F(2) = 35.6$, $p < 0.0001$; $\Delta_{S1S2} = 0.857$pts, $p_{S1S2} < 0.0001$, Cohen's $D_{S1S2} = 1.215$; $p_{S1S3} < 0.0001$, Cohen's $D_{S1S3} = 0.893$, $\Delta_{S1S3} = 0.612$pts; see Fig. 5). The teachers also noted that student motivation varied according to the themes addressed in the course. The teachers attributed this to the students having high expectations for CS in their first class which contributed to their disappointment when these themes were not taught.

> [TC journal] "The students in the first group want to learn how a computer works, understand the electronics in the computer, understand the wifi network, program a game. Those in the second group want to learn how to create a game, how to hack, open a computer and know what's inside, how wifi replaces a cable."

> [Teacher focus group] "Video games are a fantasy for them but they don't realise what's behind them. There is a mismatch between their ambitions and what they can do with their [...] background. Things look simple but there is a lot behind them."

The teachers believed that the mismatch between student expectations and the course contributed to a gradual withdrawal, which was likely exacerbated by the subject being optional and not evaluated, and therefore viewed as less important for the students.

> [Teacher focus group] "It's complicated that the course is optional. There is a withdrawal of students as there is nothing at stake. It works only on the motivation of the students. The fact that the subject is not assessed may be a problem."

> [TD journal] "Very few students were present, I had to look for them outside."

Moreover, the introduction of robotics in the second half of the semester did not seem to have contributed to an improvement of motivation in S3. This is despite robotics being associated to higher student motivation and engagement [7]. The teachers corroborated this finding by mentioning that some students had the impression that they had quickly done the rounds of the robot's functionalities. They also believed that the robotics lessons would have been better received if they had been more project oriented.

> [Teacher focus group] "The students were bored with the Thymio after 5 hours, which raises concerns about their expectations and motivation."

The course modalities, a possible cause for the drop in student motivation. Based on the findings, it would appear that the drop on motivation and mitigated course satisfaction are linked to the course's modalities, which may be lacking active, collaborative, and project-oriented elements. Therefore, while the teachers employed varied teaching methods, adaptations to the course format are still needed. For example the start of the semester focuses on mainly individual and sometimes repetitive activities (e.g. with code.org). Such an approach is more frontal, despite CS being a discipline which allows for creativity and project-based learning approaches, and thus gives the possibility to move away from the more "classical" teaching modality that is predominant in secondary schools.

[Teacher focus group] "The students don't see the point without a project. The activities are too decontextualised. That's the advantage of CS, you can [...] do projects everywhere"

[School director] "CS is typically a discipline where to motivate students and keep them captivated you can work on projects"

[Interview - Professor] "The students were missing a more creative part. We gave them the bases, but as soon as they had them we moved on to something else which was a bit frustrating."

Indeed, the teachers noted a difference between code.org which is very guided and exercise based, and Scratch which allows for more freedom.

Focus group - "code.org is too simple, very repetitive, one step out of two is enough"

And while the teachers acknowledged the benefits of Scratch for the students, they still considered it good to start with code.org was good as it required little preparation beforehand on their part. Nonetheless, the teachers believed that it would be important to have, after a few weeks, a more open and creative space like Scratch to avoid a drop in student motivation.

Heterogeneity in the classroom, a factor that adds complexity to teaching CS to all. Considering the interaction effect between time and the independent variables, this mismatch between expectations (S1) and learning perception (S2, S3) differs according to curricular orientation ($F(5) = 22.0$, $p < 0.001$). The mismatch is present for students in the general orientation ($p_{S1S2} < 0.0001$, Cohen's $D = 1.488$; $p_{S1S3} < 0.0001$, Cohen's $D_{S1S3} = 1.25$, $\Delta_{S1S3} = 0.774$pts), but not for students in the vocational orientation, despite having similar expectations in S1 ($F(1) = 0.09$, $p = 0.85$). These results highlight the issue of heterogeneity within the classes, something the teachers considered to be a factor adding complexity to their teaching and which requires adapting their teaching approach.

[TB journal] "There is a certain amount of heterogeneity [...]. Some find it too simple; I told them I could open up extra sequences for them (maybe they could do mini-projects, but with the number of pupils I can't really help them)."

[TA journal] "Some have already programmed, others not at all. The level varies a lot."

Such heterogeneity is not surprising for two reasons. First, the classes combined students in general and vocational orientation who usually have different curricula and classes. Second, there are disparities in prior CS experience, self-efficacy, familiarity with and access to Information and Communication Technologies (ICT).

[Teacher focus group] "Having mixed classes is complex. "

[Teacher focus group] "It's difficult to manage the fact that some students don't have access to computers at home."

[TB journal] "Some have trouble with the basic use of a computer. Everything takes longer as some prerequisites are not there."

[TC journal] "Students took a long time to log in because they copied their details wrong. The time is too short as soon as they have a problem logging in, it affects the flow of the session."

[TD journal] "I still notice a lack of basic computer skills. They are quickly lost."

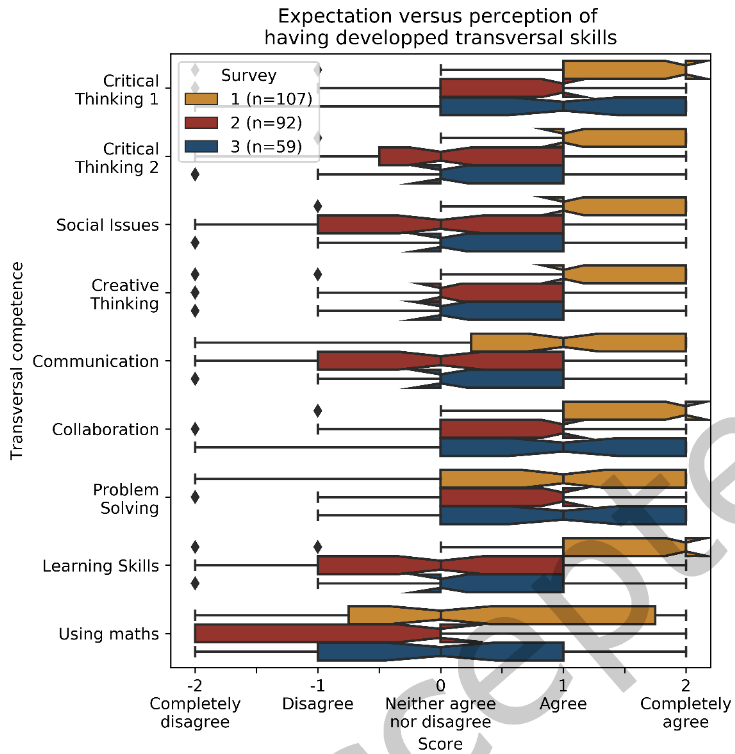

Fig. 5. Students' expectations (S1) with respect to, and perception of having developed (S2, S3), transversal competencies

[Teacher focus group] "You need to teach [the students] to use the computer before being able to program and code an algorithm."

Addressing issues of heterogeneity in the classroom. To address class-heterogeneity, the teachers made several recommendations: 1) making sure students have sufficient ICT competencies prior to following a CS course which includes coding, to avoid losing time and being able to going more in depth into certain topics; and 2) including differentiation in their teaching according to the students abilities, a point supported by the school directors and the representatives of the department of education.

[TD journal] "Two pupils already knew the Thymio and were bored [during the robot discovery activity]. It is necessary to plan differentiation activities already at this level (which I didn't have time to do...). [When discovering the programming language] some groups finished very quickly, while others did not manage to get to challenge 4. Again differentiation to be expected in this activity."

[TD journal] "You have to differentiate. Some students had already finished the exercises before I had finished explaining them..."

[Teacher focus group] "The [future CS] teachers are going to have to find a way to deal with the challenge of differentiating their teaching to address the gaps between students. There are gaps between those who were already in contact with the tools and the others. "

Reflection on the findings from all stakeholders. Nonetheless, as mentioned by the school directors, the results are encouraging. As the teachers stated, the students were curious and actively participated in the course. And, as other representatives noted, these results should be considered in their context: CS, in the context of this study, is not a graded discipline, so there is no external incentive to invest time in the course. Furthermore, they believe that the students' autonomous motivation is higher for CS than other disciplines which they have been forced to take for years, without any particular interest in them. However, as the students voluntarily participated in the pilot, motivation is likely to be lower when introduced to all students. Provided the role student motivation appears in the successful introduction of CS, adapting the course content and format in line with evidence-informed best practices [85] appears essential.

3.2 Teachers and the support received during the novel CS-course implementation

The teachers believed it was important that a course structure be provided at the start of the program by the professor and project coordinators, but appreciated having the flexibility and liberty to discuss and adjust it throughout the semester. The teachers were happy to provide feedback on the content once they had tested it, and share the adjustments they proposed.

> [Teacher focus group - TA] "It went well, we appreciated the liberty we had within the provided framework, regular meetings with [the professor]. The way we gave the lectures was flexible. We were also a small groupe which made it easier. "

> [Teacher focus group - TB] "It was all new so it was good to be able to discuss together and exchange ideas, collaborate. The feedback helped make adjustments. As it was the first time it was good to be guided. Working in a team is essential. [The professor] proposed a first plan and we worked off that. [They] proposed a framework in which we could evolve. "

> [Interview - Professor] "We discussed and exchanged ahead of time. We built things together on equal footing. We realised that the curriculum did not correspond to what [the teachers] were hoping for. So we changed it. We did the planning week by week and adjusted things."

> [Teacher focus group - TD] "We had pedagogical freedom to create the course taking into account the field. The group interactions were useful, sharing etc. and [the professors'] planning was an interesting guide that helped structure the course."

The teachers also appreciated the support of the professor, and that of the other teachers, which constituted their peer exchange group and which they considered to be an essential element of the process.

> [Teacher focus group] "The availability of [the professor] and the interactions with somebody like [them] is necessary."

> [Teacher focus group] "I proposed an escape game for the course and [the professor] helped set it up. We collaborated and [they] helped from the technical perspective. We then proposed it to the other teachers, to see if it was feasible or not, since the students need sufficient guidance. "

> [Teacher focus group] "It was important to discuss our experiences, to put things into perspective, adapt the content, and not feel alone in front of the class, to help prepare the lectures"

The findings are consistent with the literature which, in multiple cases, has raised the importance of providing teachers with adequate resources [26]. However, the content should not merely be imposed, it is also important that teachers have agency and a sense of ownership [25] when it comes to their teaching. Teachers must also be supported to be able to make such adjustments, which in this case was mainly provided by the professor. Indeed i) regular interactions with the professor, and ii) participating in a pilot program where they could freely adapt the pedagogical content, helped promote agency and ownership, which are important elements in successful teacher PD programs [14, 45] and are considered to be related to subsequent student engagement [64]. The active support provided is closely related to Grover's recommendation to involve teachers in a co-design process when looking to integrate CS into formal education [33]. Doing so will ensure that all benefit from domain expertise, as well as teachers' knowledge of classroom teaching. The teachers were nonetheless conscious that the interactions and support they had, including the inputs from research, would be complex to scale up, a point that multiple stakeholders agreed upon.

> [Interview - Professor] "Ideally the fundamental interactions should be maintained but it's very privileged. Creating a type of professional community and giving [the teachers] the means of staying in contact would help the community thrive and evolve. But you likely need an external emulation. "

> [Teacher focus group] "Next year there is a pilot over an entire year with two times as much content to handle, more teachers, without a common program, how will all of this be scaled up? The collaborations and working in a team is essential, being able to exchange regularly, and the availability of [the professor] were very important. You need to have interactions with somebody like [the professor]. And how will the research be scaled up? Having access to this dual research and training system enabled us to exchange views on what we experienced, what had happened, to put things into perspective, and to reinforce our points of view on the pupils and the content. We were not alone in front of the class, and it helped to prepare the courses. It was also useful to learn certain things that we didn't necessarily know."

3.3 Research and the RPP

3.3.1 Interactions with curriculum and PD designers. The interviewees believed the RPP, which includes multi-institution collaboration between people with expertise in various fields, including researchers, is an important facet of the regional CS-curricular reform project. Within this framework, research is considered to be important, despite being generally lacking in education settings.

> [Interview - Project coordinator] "Teaching and education needs more input from research. Few schools are focused on research and innovation, evidence, questioning ourselves, and are critical about practices. All CPDs should have somebody with a background in research and in practice, with an interest in both."

> [Interview - Professor] "It was good to communicate and interact with researchers. It was the first time we had input from the students, it was good to question them multiple times and see how things evolved."

Nonetheless, the interviewees believed that researchers aren't always sufficiently aware of the discrepancies between research findings and the reality of the field. The interactions were thus considered useful to help the researchers adapt the RQs and methodology to the field. In particular it would appear that the interviewees' teaching experience was key to understanding the field and helped them mediate between the teachers and researchers. This would appear to indicate that teachers, or stakeholders with teaching experience, should be implicated in the RPP to help bridge the research-practice gap.

> [Interview - Project coordinator] "There is often a disconnect between research and practice. There is a gap between the research world and the teaching and education world. Research is ambitious and idealistic, things appear doable and manageable. But education is not an exact science. Learning is messy, education is a messy place to work. "

> [Interview - Project coordinator] "Having a background in teaching makes it easier to find a compromise between theory and the field, and avoid the distance between practitioners and research. You can help researchers understand the terrain and adjust the research to the field."

However, the fact that researchers played the role of evaluators in the RPP framework appears to have contributed to knowledge gaps. In particular, it would have been interesting for the stakeholders to have knowledge of evidence-based best practices ahead of time (e.g. by providing high quality instructional materials [16] and being design advisors in the initial curriculum design phase [74]).

[Interview - Project coordinator] "We have no time to brush up on the literature. We are lacking a clear view of the state of the art, a clear meta-review of where we stand, and key papers. Researchers could give more with respect to the state of the art in the beginning. We need to anchor our beliefs and have something to guide our vision. "

But this requires that the different stakeholders have time to do so, and that there be clarity with respect to each stakeholders' role in the RPP.

[Interview - Professor] "A well-defined framework is needed to avoid ill-defined roles so that the expectations are clear for all".

[Interview - Professor] "There was no time to focus on the research, I needed to concentrate on creating the content. I already didn't have enough time to create the pedagogical resources so it did not feel right to invest time in research. I would have liked to be implicated in the research more, but I didn't have the time. "

3.3.2 Interactions with teachers. The teachers found it beneficial to get detailed insight into the students' perception throughout the semester, and discuss recommendations that they may implement and that may be considered for future iterations of the program.

While, in the present case, the research results were shared with the teachers, which the teachers found beneficial, the researchers mainly interacted with the project coordinators and the professor to set up the research plan. This contributed to a number of the challenges raised by the teachers within the partnership. In particular, the teachers would have liked to have more interactions with the researchers to discuss the research beforehand and suggest improvements. Both teachers and researchers would stand to benefit from this approach as teachers could provide feedback on the items and suggest improvements, all the while gaining insight into why the questions were asked and the expectations of the pilot program.

[Teacher focus group] "I would have liked to see the research question. The researchers should perhaps show the research objectives beforehand to better understand why certain questions are asked"

[Teacher focus group] "[The researchers] need to explain some elements more clearly, such as the why, the how and their expectations. It's important that we understand the survey's content and why certain questions are asked."

While the teachers did not interact with researchers in the research design phase, they actively provided feedback on the curriculum and research results, which gave them valuable insight into the students' perspective upon which they were able to act.

Without advocating that teachers be researchers, it is important to consider how teachers may collaborate with researchers on common goals to benefit all parties. The teachers would stand to gain access to usable research, opportunities to develop and apply new knowledge, professional renewal [54], as well as detailed insight into their students' perception which could benefit their teaching [48], and thus student learning. Teachers participating in action research studies were for example found to adopt a more systematic approach to integrating feedback from their students "resulting in pedagogy shifts and gains in motivation, engagement and attainment" [48]. The researchers on the other hand would stand to gain a deeper understanding of school contexts and practices, resulting in an increase in the reliability of research outcomes [25, 54]. Overall, such interactions would improve i) the quality of action- and classroom-based research, ii) translational research and the implementation of research results in teacher practices, ultimately contributing to Computing Education research being implemented in classes [72]. For such teacher-researcher interactions to be successful, it is important to consider the teacher's perception of their role in the collaboration as this may have an impact on the extent to which they feel they can provide feedback on the research design and reflect on the results of the research [25]. Finally, it is critical to have an adequate alignment between researchers' and teachers' objectives to ensure that teachers feel invested in the research results and are willing to adapt their teaching accordingly.

3.4 Study limitations

From the students' perspective, multiple limitations exist.

Firstly, the pilot targeted volunteer students, introducing a motivational bias: volunteer students are more likely to be intrinsically motivated than students who are forced to take a CS course. Motivation was also only assessed with respect to the CS course, it would have been interesting to compare their motivation in other disciplines. Continuing to evaluate students' perception of the discipline when it becomes mandatory for all is thus important as the question of ensuring continued motivation and investment throughout the program is key to making sure all students are equipped with fundamental CS competencies.

Secondly, the survey items on student learning and course evaluation were not based on validated instruments, with self-efficacy also having been evaluated using a reduced set of items, although reliability is provided by Cronbach's α for custom scales. The evaluation of self-efficacy was also benefit from more follow-up, and in depth analyses which would benefit from qualitative insight to understand it's impact on other perception dimensions. Thirdly, there was no assessment of student learning (as CS is not a graded discipline). This limitation was also raised by the teachers, who would have liked to ensure that the students were not just having fun but were also learning. Finally, as some students dropped out of the course throughout the semester (owing to the fact that the course was voluntary, was not graded and did not offer any extra credits), the response rates also decreased. While there may be selection biases, the results of the 2^{nd} and 3^{rd} surveys appear coherent.

From the teachers' perspective, the pilot program was limited to four teachers with varying prior experience in classes and with CS. They were also each affiliated to a given school, contributing to a potential confounding effect between the schools and the way the discipline was taught. Finally, aside the teacher journals, there is no direct insight into how the course was taught (e.g. through classroom observations).

From the students' and teachers' perspectives, the pilot program only evaluated one semester of CS lectures and would benefit from an analysis conducted over a longer time span and with a larger cohort of teachers and students.

From the RPP's perspective, the pilot did not assess the impact and challenges of the RPP from the point of view of all the stakeholders involved in the pilot program, and particularly the researchers.

4 DISCUSSION AND RECOMMENDATIONS

4.1 The students' perspective: the need to adapt course content, format and address biases to meet expectations and foster autonomous motivation

4.1.1 Adapting curriculum content and format. While the students volunteered to participate in the pilot CS course, they appeared to have high expectations regarding course outcomes i) in terms of topics such as gaming, hacking, and AI, and ii) with respect to the development of transversal skills such as collaboration, communication and so forth. The course, which followed a more traditional format, therefore contributed to a miss-match between the course which presented foundational CS-concepts in a traditional approach, and their expectations. This contributed to a drop in student motivation throughout the semester, with less students attending the course close to the end of the semester. It thus appears essential to adapt the course content and format considering the likely increase in extrinsic regulation once the course is mandatory for all (a point indeed raised by multiple stakeholders, including the school directors). As stated by the NCWIT [23] engagement practices framework "all students are more motivated, perform better, and more likely to persist when they can see how a lesson connects to their experiences, interests, goals, and values. And students who don't fit the stereotype of someone pursuing computing may need even more explicit connections for them to envision themselves in the field" [1].

To that effect, adapting the course format to be more active, collaborative and project-oriented could contribute to promoting intrinsic motivation, especially considering that CS is well suited to such an approach. Indeed, employing project-based learning with authentic real-world scenarios has been shown to promote student motivation [12, 18, 47], and is more effective when teachers have the agency to make "instructional decisions and adapt project based learning to support students' needs" [64] Projects also make it possible to align the learning activities with the topics the students expressed being interested in (e.g. gaming and AI, 40). Considering that students have varying interests, a project-based learning approach may therefore help make CS engaging to a wider and more diverse audience [49], including those not initially interested in CS (e.g. by having projects in relation to other school subjects, which has also been found to motivate teachers to deepen project based learning practices [64]). Similarly, a recent study [40] showed that game development in secondary school which was linked to solving real-world problems promoted student motivation when learning how to program. Another promising avenue appears to be "CS for social good" which was shown to improve students' CS perception and self-efficacy [9]. It would therefore be interesting to clarify and make explicit the link between activities in the curriculum and real-world applications that interest students in order to contribute to improving the students' identified regulation and lower the risk of students experiencing disappointment as in the present context. Indeed, strategies that explicitly highlight the link between CS and real world applications are closely related to the benefits of introducing proximal (short term) and distal goals (long term). Proximal and distal goals have been shown to improve performance [71], with proximal goals specifically helping increase self-efficacy and intrinsic interest in activities that initially fostered little student interest [5]. Finally, as the directors proposed, highlighting the utility of CS by reinforcing the link between CS and real-life could be achieved by inviting professionals to explain the role of CS in their careers. Similarly, discussions with students at the start of the program to identify their interests and tailor the course and group projects accordingly could help foster engagement and motivation towards the course.

4.1.2 Addressing CS-related gender biases and heterogeneity to broaden CS participation. The study indicated the presence of gender-related differences and heterogeneity already in grade 9. Addressing both requires considering two temporalities: preventive actions, and solutions for teachers presently facing said issues.

Gender-related differences appear in terms of self-efficacy, motivation and prior experience with CS. Indeed, attitudes towards CS have been found to correlate with CS-performance [76, 81], with gender-related biases being one reason for under representation of women in STEM-related fields [88]. Multiple studies have also shown that gender-related disparities and stereotypes (which run the risk of triggering stereotype threats, and affecting decisions), appear early [53]. An analysis of 960 students' attitudes towards computing [50] showed that gender-related differences were already present for 10-year-old students. As prior experiences help build up self-efficacy [4, 37], the introduction of CS as a discipline prior to secondary school appears essential to ensure that all students learn the fundamentals of CS. This aligns with Leonard et al. [50]'s recommendation to promote early interventions focusing on self-efficacy, attitudes and perception to ensure an increased representation of female students in CS in the long term.

Introducing CS in primary school education could not only help reduce gender-related gaps and overall under-representation in the field [11, 44], but could also contribute to broadening participation more globally in CS education by ensuring that all students have access to CS instruction, thus addressing structural gaps [83, 87] (and, as such, reduce the heterogeneity present in secondary school). Indeed, prior CS experience has been found to have a significant impact on CS attitudes [39] and is believed to have the potential to address issues pertaining to gender equity [11, 39, 44]. Nonetheless, if CS is not an evaluated discipline, students' implication in the course is heavily based on their intrinsic motivation. This runs the risk of increasing disparities between students, rather than ensuring that all reach the learning objectives.

Finally, considering teachers presently facing heterogeneity in the classroom, one solution was proposed by the teachers and stakeholders: integrating differentiation in lessons. Such an approach would help ensure that students remain in a “motivational zone [that is] optimally challenging because tasks are calibrated to the learner’s level” [86]. It is important to keep in mind that this may introduce additional challenges for teachers in terms of preparation and classroom orchestration.

4.2 The teacher’s perspective: the need for scalable support within schools

The findings in terms of the teachers’ perspective highlight the importance of establishing adequate support in their implementation of the curriculum. This appears in two forms: coaching, which was provided here by regular interactions with the professor, and the emerging community of practice. Ongoing support and providing teachers with feedback and the means to reflect on their teaching over a sustained duration constitute some of the requirements for PD quality [21, 30]. This, however, can be difficult to scale up when considering the widespread introduction of CS into teacher practices. One means of approaching this is by considering the role the professor played in the present context, which was close to that of an instructional coach. As stated by Liao et al. [51], “providing coaching to change teachers’ teaching practices is not a new method in K-12 schools. However, coaching has not yet been widely implemented and researched in teacher PD for technology integration.” This is despite the benefits that coaching may have on the sustained adoption of the discipline [22] and scalability of the curricular reform [14]. One key element for successful coaching is raised by Liao et al. [51]: there should be a “healthy coach-teacher relationship with sufficient communication and reflection”. And while this was achieved in the present scenario, it is important to reflect on how this may be scaled up to widespread CS-related curricular reform, a limitation raised by the teachers themselves. One approach which was recently employed was to train teachers in schools to be instructional coaches for their peers [10, 26]. However, the question of their role within the schools, and their professional development becomes critical as they must have competencies which extend beyond the mastery of core CS concepts [10, 59]. Part of their role can nonetheless include that of managing a community of practice within their school so that teachers may engage in regular joint activities and discussions, as well as developing a shared repertoire of resources to improve their CS-practice [90]. Another possible avenue of interest may be blended communities of practices [80] which are independent of having instructional coaches in schools.

4.3 The RPP’s perspective: the need to include teachers in all aspects of the RPP and reconsider researchers’ roles in the RPP

Establishing an RPP and involving researchers in CS-curricular reforms appears beneficial in providing evidence-informed recommendations for future applications. However, the fact that CS curricular reforms and PD programs run into challenges such as those reported in the article confirms that there is, as mentioned by Sentance [72], a gap between computing education research and its application in the field. While the pilot was embedded within the context of a regional RPP, there are still challenges that contribute to both i) the research-practice gap between researchers and teachers who “occupy a dual space as both the recipient of project interventions and a critical voice within the project” [54], and ii) the fact that effective ways of teaching computing are not reaching schools and teachers. In the present case it would appear that many challenges were due to the researchers in computing education not being directly involved in the curriculum creation or teacher PD, and due to teachers not being involved in the research planning, despite the importance of “establish norms of interaction that support collaborative decision making and equitable participation in all phases of the work” [38]. However, it is important to remain aware of other challenges which have implications for the application of evidence-informed Computing Education best practices in schools [72] : concerns about the quality of education research, teachers’ lack of agency around research and the fact that policy makers’, educators’ and researchers’ priorities often differ.

One advantage of the present RPP is the inclusion of a pilot program which the researchers evaluated to draw recommendations for future iterations of the program before large scale deployment [26], while factoring in the constraints of the field and various stakeholders involved. The present RPP should, however, reconsider the role of researchers in the process. Indeed, researchers' roles in RPPs can be diverse and vary between proposing research plans, supporting the development of pedagogical content knowledge, collaborating with district leaders, providing knowledge and evidence, and "bring[ing] connections to external supports for implementation and evaluat[ing] and disseminat[ing] findings" [54]. As such, in the present case, it is important to reconsider how researchers may be more directly involved with teachers, and in the development of curriculum, rather than having a mainly evaluative role.

Finally, and more generally, including teachers and practitioners with teaching experience in the RPP, and giving them an equal voice within the partnership, appears essential to the success of the curricular reform by giving teachers agency, a sense of ownership and ultimately gaining their acceptance. Indeed, giving teachers "a critical voice within the project" [54] would contribute to an improved alignment between the RPP's interventions and the constraints of the field. This also provides the opportunity to have teachers interact with researchers directly. Such interactions should be exploited to help bridge the research-practice gap often mentioned in the literature, and benefit all parties [25, 72]. On the one hand it is possible to promote the application of computing education research in schools, an element which is presently lacking globally [72]. On the other hand, these interactions would contribute to increasing the quality of computing education research [72].

To conclude, finding an adequate means of including teachers and integrating research within the RPP would help ensure that there is an adequate alignment between the objectives of all the partners, that knowledge is shared and built with all stakeholders [54], and that evidence-informed Computing Education best practices are implemented. Such interactions would ultimately contribute to the quality of the endeavour but requires that all stakeholders have enough time to interact with researchers ahead of time, in addition to their other responsibilities. Finally, to avoid power struggles and tensions among RPP partners, it is important to clearly define each partners' roles and responsibilities when setting up the RPP [54], in particular in contexts where it is uncommon to have inter-institutional collaborations that include research.

5 CONCLUSION

The introduction of CS into formal education is a challenging ongoing endeavour worldwide which involves numerous stakeholders. Building upon the fact that Research Practice Partnerships are considered to provide solutions that are more sustainable and scalable [15], in this article we argue that the multiple perspectives of the stakeholders within it must be considered simultaneously in order to effectively introduce the discipline:

- *the students' perspective* in order to ensure their persistence in the field;
- *the teachers' perspective* in order to ensure the sustainability of the integration of the discipline into teachers' practices while accounting for the reality and constraints of the field;
- *the research practice partnership's stakeholders' perspective*, including other key school and district level stakeholders, to co-construct the reform and facilitate the introduction of the discipline into schools, all the while ensuring that evidence-informed best practices are applied in both the teacher professional development and in schools.

However, as the study of the pilot program to introduce CS into secondary school has shown, there are inherent difficulties related to the introduction of the discipline and such partnerships which we believe should be addressed in order to improve the success of CS-curricular reforms:

- Students have high expectations of CS courses which lead to disappointment and disengagement with the course. We recommend that CS courses have an adapted course format and content which is engaging,

notably in contexts where it is optional to take a CS course (for instance by introducing more project oriented experiences in the course with relevant real world applications to engage all students in the course)
- Gender gaps and differences in prior CS experience are already present in early secondary school. We recommend that these be addressed through early experiences to positively affect attitudes and avoid exacerbating already existing social and structural barriers related to the computing field [87] (for instance by introducing the discipline for all starting primary school).
- A PD and accompaniment model where the teachers have regular interactions with an expert in the field, and the creation of a small community of practice were key to the teachers' positive perception of the pilot experience but are difficult to scale. We recommend that alternative solutions where it is possible to maintain such dynamics within schools be considered for piloting and large scale deployment through solutions such as in-school instructional coaches.
- There are numerous benefits to having a research practice partnership and including teachers as key stakeholders in the partnership. However, we recommend that the role of researchers in the partnership be reconsidered from two perspectives to benefit the partnership's outcomes : 1) moving away from being mainly evaluators of the project outcomes with increased participation in the conception phases in order to inform regarding computing education best practices from the start of the program, and 2) establishing concrete means of having researchers interact directly with the teachers in the field in a way that may benefit both parties [25, 55].

The recommendations discussed in the article could be of relevance to those participating in curricular reforms and research practice partnerships, notably considering the importance of finding solutions that are scalable, sustainable and adapted to the constraints of the field and its various stakeholders.

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REFERENCES

[1] 2021. Engagement Practices Framework | National Center for Women & Information Technology. https://ncwit.org/engagement-practices-framework/

[2] W. Richards Adrion, Katie Bevan, Paul Foster, Denise Matuszczak, Rachel Miller, Laura Rita, Florence R. Sullivan, Sneha Veeragoudar, Scott Wohlers, and Melissa Zeitz. 2022. How a Research-Practice Partnership Refined its Strategy for Integrating CS/CT into K-5 Curricula: An Experience Report. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1 (SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 592–598. https://doi.org/10.1145/3478431.3499281

[3] Christophe Angot. 2013. *La dynamique de la motivation situationnelle.* Ph. D. Dissertation. Limoges.

[4] Albert Bandura. 1993. Perceived self-efficacy in cognitive development and functioning. *Educational psychologist* 28, 2 (1993), 117–148.

[5] Albert Bandura and Dale H Schunk. 1981. Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of personality and social psychology* 41, 3 (1981), 586.

[6] Karen A. Blotnicky, Tamara Franz-Odendaal, Frederick French, and Phillip Joy. 2018. A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *IJ STEM Ed* 5, 1 (May 2018), 22. https://doi.org/10.1186/s40594-018-0118-3

[7] Jérôme Brender, Laila El-Hamamsy, Barbara Bruno, Frédérique Chessel-Lazzarotto, Jessica Dehler Zufferey, and Francesco Mondada. 2021. Investigating the Role of Educational Robotics in Formal Mathematics Education: The Case of Geometry for 15-Year-Old Students. In *Technology-Enhanced Learning for a Free, Safe, and Sustainable World*. Springer International Publishing, 67–81.

[8] Hein Broekkamp and Bernadette van Hout-Wolters. 2007. The gap between educational research and practice: A literature review, symposium, and questionnaire. *Educational Research and Evaluation* 13, 3 (June 2007), 203–220. https://doi.org/10.1080/13803610701626127

[9] Caelin Bryant, Yesheng Chen, Zhen Chen, Jonathan Gilmour, Shyamala Gumidyala, Beatriz Herce-Hagiwara, Annabella Koures, Seoyeon Lee, James Msekela, Anh Thu Pham, Halle Remash, Marli Remash, Nolan Schoenle, Jonah Zimmerman, Sarah Dahlby Albright, and Samuel A. Rebelsky. 2019. A Middle-School Camp Emphasizing Data Science and Computing for Social Good. In *Proc. 50th ACM Tech. Symp. Comput. Sci. Educ. (SIGCSE '19)*. ACM, 358–364. https://doi.org/10.1145/3287324.3287510

[10] Christiane Caneva, Monnier Emilie-Charlotte, Caroline Pulfrey, Laila El-Hamamsy, Sunny Avry, and Jessica Dehler Zufferey. 2022. *Technology Integration needs Empowered Instructional Coaches: Accompanying In-service Teachers in School Digitalization.*

[11] Sapna Cheryan, Sianna A. Ziegler, Amanda K. Montoya, and Lily Jiang. 2017. Why are some STEM fields more gender balanced than others? *Psychological Bulletin* 143, 1 (Jan. 2017), 1–35. https://doi.org/10.1037/bul0000052 Num Pages: 1-35 Publisher: American Psychological Association (US).

[12] C. L. Chiang and H. Lee. 2016. The Effect of Project-Based Learning on Learning Motivation and Problem-Solving Ability of Vocational High School Students. *IJIET* 6, 9 (2016), 709–712. https://doi.org/10.7763/IJIET.2016.V6.779

[13] Cynthia Coburn, Jennifer Russell, Julia Kaufman, and Mary Stein. 2012. Supporting Sustainability: Teachers' Advice Networks and Ambitious Instructional Reform. *American Journal of Education* 119 (Nov. 2012), 137–182. https://doi.org/10.1086/667699

[14] Cynthia E. Coburn. 2003. Rethinking Scale: Moving Beyond Numbers to Deep and Lasting Change. *Educational Researcher* 32, 6 (Aug. 2003), 3–12. https://doi.org/10.3102/0013189X032006003

[15] Cynthia E. Coburn and William R. Penuel. 2016. Research–Practice Partnerships in Education: Outcomes, Dynamics, and Open Questions. *Educational Researcher* 45, 1 (Jan. 2016), 48–54. https://doi.org/10.3102/0013189X16631750 Publisher: American Educational Research Association.

[16] Cynthia E. Coburn, William R. Penuel, and Caitlin C. Farrell. 2021. Fostering educational improvement with research-practice partnerships. *Phi Delta Kappan* 102, 7 (April 2021), 14–19. https://doi.org/10.1177/00317217211007332 Publisher: SAGE Publications Inc.

[17] Marilyn Cochran-Smith and Susan L. Lytle. 1999. Relationships of Knowledge and Practice: Teacher Learning in Communities. *Review of Research in Education* 24 (1999), 249–305. https://doi.org/10.2307/1167272

[18] European Commission, Joint Research Centre, S Bocconi, A Chioccariello, P Kampylis, V Dagienė, P Wastiau, K Engelhardt, K Earp, M Horvath, M Jasutė, C Malagoli, V Masiulionytė-Dagienė, G Stupurienė, and N Giannoutsou. 2022. *Reviewing computational thinking in compulsory education : state of play and practices from computing education.* https://doi.org/doi/10.2760/126955

[19] John W. Creswell and Cheryl N. Poth. 2018. *Qualitative inquiry & research design: choosing among five approaches* (fourth edition ed.). SAGE, Los Angeles. OCLC: ocn954104455.

[20] Linda Darling-Hammond. 2012. *Powerful Teacher Education: Lessons from Exemplary Programs.* John Wiley & Sons.

[21] Linda Darling-Hammond, Maria E. Hyler, and Madelyn Gardner. 2017. *Effective Teacher Professional Development.* Learning Policy Institute.

[22] Kim E. Dooley. 1999. Towards a Holistic Model for the Diffusion of Educational Technologies: An Integrative Review of Educational Innovation Studies. *Journal of Educational Technology & Society* 2, 4 (1999), 35–45.

[23] Wendy M DuBow, Beth A Quinn, Gloria Childress Townsend, Rosario Robinson, and Valerie Barr. 2016. Efforts to make computer science more inclusive of women. *ACM Inroads* 7, 4 (2016), 74–80.

[24] Birgit Eickelmann. 2013. Supportive and hindering factors to a sustainable implementation of ICT in schools. *Journal for Educational Research Online* (April 2013). https://doi.org/10.25656/01:4683 Publisher: Waxmann.

[25] Laila El-Hamamsy, Barbara Bruno, Helena Kovacs, Morgane Chevalier, Jessica Dehler Zufferey, and Francesco Mondada. 2022. A case for co-construction with teachers in curricular reform: Introducing computer science in primary school. In *Australasian Computing Education Conference (ACE '22)*. ACM, 56–65. https://doi.org/10.1145/3511861.3511883

[26] Laila El-Hamamsy, Frédérique Chessel-Lazzarotto, Barbara Bruno, Didier Roy, Tereza Cahlikova, Morgane Chevalier, Gabriel Parriaux, Jean-Philippe Pellet, Jacques Lanarès, Jessica Dehler Zufferey, and Francesco Mondada. 2021. A computer science and robotics integration model for primary school: evaluation of a large-scale in-service K-4 teacher-training program. *Educ Inf Technol* 26, 3 (May 2021), 2445–2475. https://doi.org/10.1007/s10639-020-10355-5

[27] Katrina Falkner, Sue Sentance, Rebecca Vivian, Sarah Barksdale, Leonard Busuttil, Elizabeth Cole, Christine Liebe, Francesco Maiorana, Monica M. McGill, and Keith Quille. 2019. An International Comparison of K-12 Computer Science Education Intended and Enacted Curricula. In *Proc. 19th Koli Calling International Conference on Computing Education Research.* ACM, 1–10. https://doi.org/10.1145/3364510.3364517

[28] Caitlin C. Farrell, Laura Wentworth, and Michelle Nayfack. 2021. What are the conditions under which research-practice partnerships succeed? *Phi Delta Kappan* 102, 7 (April 2021), 38–41. https://doi.org/10.1177/00317217211007337

[29] Luca Forlizzi, Michael Lodi, Violetta Lonati, Claudio Mirolo, Mattia Monga, Alberto Montresor, Anna Morpurgo, and Enrico Nardelli. 2018. A Core Informatics Curriculum for Italian Compulsory Education. In *Informatics in Schools. Fundamentals of Computer Science and Software Engineering (Lect. Notes Comput. Sci.)*, Sergei N. Pozdniakov and Valentina Dagienė (Eds.). Springer International Publishing, 141–153. https://doi.org/10.1007/978-3-030-02750-6_11

[30] Michelle Friend, Bryan Twarek, James Koontz, Amanda Bell, and Abigail Joseph. 2022. Trends in CS Teacher Professional Development: A Report from the CSTA PD Committee. In *Proc. 53rd ACM Tech. Symp. Comput. Sci. Educ. V. 1 (SIGCSE 2022)*. ACM, 390–396. https:

//doi.org/10.1145/3478431.3499292

[31] Marylène Gagné, Jacques Forest, Marie-Hélène Gilbert, Caroline Aubé, Estelle Morin, and Angela Malorni. 2010. The motivation at work scale: Validation evidence in two languages. *Educational and psychological measurement* 70, 4 (2010), 628–646.

[32] Wendy S Grolnick and Richard M Ryan. 1989. Parent styles associated with children's self-regulation and competence in school. *Journal of educational psychology* 81, 2 (1989), 143.

[33] Shuchi Grover. 2021. *'CTIntegration': A Conceptual Framework Guiding Design and Analysis of Integration of Computing and Computational Thinking Into School Subjects.* Technical Report. EdArXiv. https://doi.org/10.35542/osf.io/eg8n5

[34] Xiaoqing Gu, Charles Crook, and Mike Spector. 2019. Facilitating innovation with technology: Key actors in educational ecosystems. *British journal of educational technology* 50, 3 (2019), 1118–1124. https://dialnet.unirioja.es/servlet/articulo?codigo=6935428 Publisher: British Educational Research Association Section: British journal of educational technology.

[35] Frédéric Guay, Robert J Vallerand, and Céline Blanchard. 2000. On the assessment of situational intrinsic and extrinsic motivation: The Situational Motivation Scale (SIMS). *Motivation and emotion* 24, 3 (2000), 175–213.

[36] Thomas R Guskey. 2000. *Evaluating professional development.* Corwin press.

[37] Ove Edvard Hatlevik, Inger Throndsen, Massimo Loi, and Greta B. Gudmundsdottir. 2018. Students' ICT self-efficacy and computer and information literacy: Determinants and relationships. *Computers & Education* 118 (March 2018), 107–119. https://doi.org/10.1016/j.compedu.2017.11.011

[38] Erin C Henrick, Paul Cobb, William R Penuel, Kara Jackson, and Tiffany Clark. 2017. Assessing Research-Practice Partnerships: Five Dimensions of Effectiveness. (2017), 31.

[39] Madeline Hinckle, Arif Rachmatullah, Bradford Mott, Kristy Elizabeth Boyer, James Lester, and Eric Wiebe. 2020. The Relationship of Gender, Experiential, and Psychological Factors to Achievement in Computer Science. In *Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education (ITiCSE '20).* Association for Computing Machinery, New York, NY, USA, 225–231. https://doi.org/10.1145/3341525.3387403

[40] Martina Holenko Dlab and Natasa Hoic-Bozic. 2021. Effectiveness of game development-based learning for acquiring programming skills in lower secondary education in Croatia. *Educ Inf Technol* (March 2021). https://doi.org/10.1007/s10639-021-10471-w

[41] Joshua L. Howard, Julien Bureau, Frédéric Guay, Jane X. Y. Chong, and Richard M. Ryan. 2021. Student Motivation and Associated Outcomes: A Meta-Analysis From Self-Determination Theory. *Perspect Psychol Sci* 16, 6 (Nov. 2021), 1300–1323. https://doi.org/10.1177/1745691620966789

[42] Joshua L. Howard, Marylène Gagné, Anja Van den Broeck, Frédéric Guay, Nikos Chatzisarantis, Nikos Ntoumanis, and Luc G. Pelletier. 2020. A review and empirical comparison of motivation scoring methods: An application to self-determination theory. *Motiv Emot* 44, 4 (Aug. 2020), 534–548. https://doi.org/10.1007/s11031-020-09831-9

[43] Mireille D. Hubers. 2020. Paving the way for sustainable educational change: Reconceptualizing what it means to make educational changes that last. *Teaching and Teacher Education* 93 (July 2020), 103083. https://doi.org/10.1016/j.tate.2020.103083

[44] Shan Jiang and Gary K. W. Wong. 2022. Exploring age and gender differences of computational thinkers in primary school: A developmental perspective. *Journal of Computer Assisted Learning* 38, 1 (2022), 60–75. https://doi.org/10.1111/jcal.12591

[45] Herma Jonker, Virginie März, and Joke Voogt. 2019. Collaboration in teacher design teams: Untangling the relationship between experiences of the collaboration process and perceptions of the redesigned curriculum. *Studies in Educational Evaluation* 61 (June 2019), 138–149. https://doi.org/10.1016/j.stueduc.2019.03.010

[46] Panagiotis Kampylis, Nancy Law, Yves Punie, Stefania Bocconi, Barbara Brecko, Seungyeon Han, Chee-Kit Looi, and Naomi Miyake. 2013. *ICT-enabled innovation for learning in Europe and Asia. Exploring conditions for sustainability, scalability and impact at system level.* Technical Report JRC83503. Joint Research Centre (Seville site). https://ideas.repec.org/p/ipt/iptwpa/jrc83503.html Publication Title: JRC Working Papers.

[47] Shui-fong Lam, Rebecca Wing-yi Cheng, and William Y. K. Ma. 2008. Teacher and student intrinsic motivation in project-based learning. *Instr Sci* 37, 6 (Sept. 2008), 565. https://doi.org/10.1007/s11251-008-9070-9

[48] Andrew Lambirth and Ana Cabral. 2017. Issues of agency, discipline and criticality: an interplay of challenges involved in teachers engaging in research in a performative school context. *Educational Action Research* 25, 4 (Aug. 2017). https://doi.org/10.1080/09650792.2016.1218350

[49] Ákos Lédeczi, Shuchi Grover, Veronica Catete, and Brian Broll. 2021. Beyond CS Principles: Bringing the Frontiers of Computing to K12. In *Proc. 52nd ACM Tech. Symp. Comput. Sci. Educ. (SIGCSE '21).* ACM, 1379. https://doi.org/10.1145/3408877.3439542

[50] Hayley C. Leonard, Oliver Quinlan, and Sue Sentance. 2021. Female pupils' attitudes to computing in early adolescence. In *United Kingdom and Ireland Computing Education Research conference.* ACM, 1–6. https://doi.org/10.1145/3481282.3481289

[51] Yin-Chan Liao, Anne Ottenbreit-Leftwich, Krista Glazewski, and Michael Karlin. 2021. Coaching to support teacher technology integration in elementary classrooms: A multiple case study. *Teaching and Teacher Education* 104 (Aug. 2021), 103384. https://doi.org/10.1016/j.tate.2021.103384

[52] Angus J. MacNeil, Doris L. Prater, and Steve Busch. 2009. The effects of school culture and climate on student achievement. *International Journal of Leadership in Education* 12, 1 (Jan. 2009), 73–84. https://doi.org/10.1080/13603120701576241

[53] Allison Master, Andrew N. Meltzoff, and Sapna Cheryan. 2021. Gender stereotypes about interests start early and cause gender disparities in computer science and engineering. *Proc Natl Acad Sci USA* 118, 48 (Nov. 2021), e2100030118. https://doi.org/10.1073/pnas.2100030118

[54] Monica M. McGill, Alan Peterfreund, Stacey Sexton, Rebecca Zarch, and Maral Kargarmoakhar. 2021. Exploring research practice partnerships for use in K–12 computer science education. *ACM Inroads* 12, 3 (Aug. 2021), 24–31. https://doi.org/10.1145/3477607

[55] Monica M. McGill and Anni Reinking. 2022. Early Findings on the Impacts of Developing Evidence-Based Practice Briefs on Middle School Computer Science Teachers. *ACM Trans. Comput. Educ.* (June 2022). https://doi.org/10.1145/3543512 Just Accepted.

[56] Sharan B. Merriam and Elizabeth J. Tisdell. 2015. *Qualitative research: a guide to design and implementation* (4th ed.). John Wiley & Sons, San Francisco, CA.

[57] Dale S. Niederhauser, Sarah K. Howard, Joke Voogt, Douglas D. Agyei, Therese Laferriere, Jo Tondeur, and Margaret J. Cox. 2018. Sustainability and Scalability in Educational Technology Initiatives: Research-Informed Practice. *Tech Know Learn* 23, 3 (Oct. 2018), 507–523. https://doi.org/10.1007/s10758-018-9382-z

[58] E. Olivier, I. Archambault, M. De Clercq, and B. Galand. 2019. Student Self-Efficacy, Classroom Engagement, and Academic Achievement: Comparing Three Theoretical Frameworks. *J Youth Adolescence* 48, 2 (Feb. 2019), 326–340. https://doi.org/10.1007/s10964-018-0952-0

[59] Susanne Owen. 2014. Teacher Professional Learning Communities: Going beyond Contrived Collegiality toward Challenging Debate and Collegial Learning and Professional Growth. *Aust. J. Adult Learn.* 54, 2 (July 2014), 54–77.

[60] David C. Owens, Troy D. Sadler, Angela T. Barlow, and Cindi Smith-Walters. 2020. Student Motivation from and Resistance to Active Learning Rooted in Essential Science Practices. *Res Sci Educ* 50, 1 (Feb. 2020), 253–277. https://doi.org/10.1007/s11165-017-9688-1

[61] Michael Quinn Patton and Michael Quinn Patton. 2002. *Qualitative research and evaluation methods* (3 ed ed.). Sage Publications, Thousand Oaks, Calif.

[62] Jules Pieters, Joke Voogt, and Natalie Pareja Roblin (Eds.). 2019. *Collaborative Curriculum Design for Sustainable Innovation and Teacher Learning.* Springer Nature. https://doi.org/10.1007/978-3-030-20062-6 Accepted: 2020-03-18 13:36:15.

[63] Paul R Pintrich and Elisabeth V De Groot. 1990. Motivational and self-regulated learning components of classroom academic performance. *Journal of educational psychology* 82, 1 (1990), 33.

[64] Ashley Seidel Potvin, Emily Adah Miller, Rachel Kuck, Leema Kuhn Berland, Alison G. Boardman, Sarah Schneider Kavanagh, Tiffany Lee Clark, and Britte Haugan Cheng. 2022. Mapping Enabling Conditions for High-Quality PBL: A Collaboratory Approach. *Education Sciences* 12, 3 (March 2022), 222. https://doi.org/10.3390/educsci12030222

[65] Mitchel Resnick, Brian Silverman, Yasmin Kafai, John Maloney, Andrés Monroy-Hernández, Natalie Rusk, Evelyn Eastmond, Karen Brennan, Amon Millner, Eric Rosenbaum, and Jay Silver. 2009. Scratch: programming for all. *Commun. ACM* 52, 11 (Nov. 2009), 60. https://doi.org/10.1145/1592761.1592779

[66] Fanny Riedo, Morgane Chevalier, Stephane Magnenat, and Francesco Mondada. 2013. Thymio II, a robot that grows wiser with children. In *2013 IEEE Workshop on Advanced Robotics and its Social Impacts.* IEEE, 187–193. https://doi.org/10.1109/ARSO.2013.6705527

[67] Marine Roche. 2019. *L'acceptation d'un nouvel enseignement à l'école primaire : les professeurs des écoles face à la programmation informatique.* thesis. Nantes. http://www.theses.fr/2019NANT2030

[68] Richard M. Ryan and Edward L. Deci. 2020. Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology* 61 (April 2020), 101860. https://doi.org/10.1016/j.cedpsych.2020.101860

[69] Johnny Saldaña. 2009. *The coding manual for qualitative researchers.* Sage, Los Angeles, California.

[70] André Schiper. 2016. *Découvrir le numérique: une introduction à l'informatique et aux systèmes de communications.* Presses polytechniques et universitaires romandes.

[71] Gerard H. Seijts and Gary P. Latham. 2001. The effect of distal learning, outcome, and proximal goals on a moderately complex task. *Journal of Organizational Behavior* 22, 3 (2001). https://doi.org/10.1002/job.70

[72] Sue Sentance. 2021. Teaching computing in school: is K-12 research reaching classroom practice?. In *21st Koli Calling International Conference on Computing Education Research.* ACM, 1–2. https://doi.org/10.1145/3488042.3491040

[73] Matthew Shirrell and James P. Spillane. 2020. Opening the door: Physical infrastructure, school leaders' work-related social interactions, and sustainable educational improvement. *Teaching and Teacher Education* 88 (Feb. 2020), 102846. https://doi.org/10.1016/j.tate.2019.05.012

[74] Simon Sjölund, J. Lindvall, M. Larsson, and A. Ryve. 2022. Mapping roles in research-practice partnerships – a systematic literature review. *Educational Review* (Feb. 2022), 1–29. https://doi.org/10.1080/00131911.2021.2023103

[75] Simon Sjölund, Jannika Lindvall, Maria Larsson, and Andreas Ryve. 2022. Using research to inform practice through research-practice partnerships: A systematic literature review. *Review of Education* 10, 1 (2022), e3337. https://doi.org/10.1002/rev3.3337

[76] Lihui Sun, Linlin Hu, and Danhua Zhou. 2022. Programming attitudes predict computational thinking: Analysis of differences in gender and programming experience. *Computers & Education* 181 (May 2022), 104457. https://doi.org/10.1016/j.compedu.2022.104457

[77] Mei Ying Tan and David Wei Loong Hung. 2020. Models of innovation scaling in Singapore schools: process objects as multi-level role clusters and outcomes—a multiple case study approach. *Asia Pacific Educ. Rev.* 21, 4 (Dec. 2020), 553–571.

[78] The Royal Society. 2017. *After the reboot: computing education un UK schools.*

[79] Lotta Tikkanen, Kirsi Pyhältö, Janne Pietarinen, and Tiina Soini. 2020. Lessons learnt from a large-scale curriculum reform: The strategies to enhance development work and reduce reform-related stress. *J Educ Change* 21, 4 (Nov. 2020), 543–567. https://doi.org/10.1007/s10833-019-09363-1

[80] Torrey Trust and Brian Horrocks. 2017. 'I never feel alone in my classroom': teacher professional growth within a blended community of practice. *Professional Development in Education* 43, 4 (Aug. 2017), 645–665. https://doi.org/10.1080/19415257.2016.1233507

[81] Meng-Jung Tsai, Francis Pingfan Chien, Silvia Wen-Yu Lee, Chung-Yuan Hsu, and Jyh-Chong Liang. 2022. Development and Validation of the Computational Thinking Test for Elementary School Students (CTT-ES): Correlate CT Competency With CT Disposition. *Journal of Educational Computing Research* (Jan. 2022). https://doi.org/10.1177/07356331211051043

[82] Jan van den Akker. 2003. Curriculum Perspectives: An Introduction. In *Curriculum Landscapes and Trends*, Jan van den Akker, Wilmad Kuiper, and Uwe Hameyer (Eds.). Springer Netherlands, Dordrecht, 1–10. https://doi.org/10.1007/978-94-017-1205-7_1

[83] Jessica Vandenberg, Arif Rachmatullah, Collin Lynch, Kristy E. Boyer, and Eric Wiebe. 2021. Interaction effects of race and gender in elementary CS attitudes: A validation and cross-sectional study. *International Journal of Child-Computer Interaction* 29 (Sept. 2021), 100293. https://doi.org/10.1016/j.ijcci.2021.100293

[84] Jane Waite, Andrea Franceschini, Sue Sentance, Mathew Patterson, and James Sharkey. 2021. *An Online Platform for Teaching Upper Secondary School Computer Science.* Association for Computing Machinery, New York, NY, USA.

[85] Jane Waite and Sue Sentance. 2021. Teaching programming in schools: A review of approaches and strategies. (2021), 54.

[86] R. A. Walker. 2010. Sociocultural Issues in Motivation. In *International Encyclopedia of Education (Third Edition)*, Penelope Peterson, Eva Baker, and Barry McGaw (Eds.). Elsevier, Oxford, 712–717. https://doi.org/10.1016/B978-0-08-044894-7.00629-1

[87] Jennifer Wang and Sepehr Hejazi Moghadam. 2017. Diversity Barriers in K-12 Computer Science Education: Structural and Social. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education (SIGCSE '17)*. Association for Computing Machinery, New York, NY, USA, 615–620. https://doi.org/10.1145/3017680.3017734

[88] Ming-Te Wang and Jessica L. Degol. 2017. Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy, and Future Directions. *Educ Psychol Rev* 29, 1 (March 2017), 119–140. https://doi.org/10.1007/s10648-015-9355-x

[89] Ming-Te Wang, Jiesi Guo, and Jessica L. Degol. 2020. The Role of Sociocultural Factors in Student Achievement Motivation: A Cross-Cultural Review. *Adolescent Res Rev* 5, 4 (Dec. 2020), 435–450. https://doi.org/10.1007/s40894-019-00124-y

[90] Etienne Wenger. 2011. Communities of practice: A brief introduction. (Oct. 2011).

[91] Bian Wu, Xiaoxue Yu, and Yiling Hu. 2019. How does principal e-leadership affect ICT transformation across different school stages in K-12 education: Perspectives from teachers in Shanghai. *British Journal of Educational Technology* 50, 3 (2019), 1210–1225. https://doi.org/10.1111/bjet.12766 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/bjet.12766.

[92] Barry J. Zimmerman. 2000. Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology* 25, 1 (Jan. 2000), 82–91. https://doi.org/10.1006/ceps.1999.1016