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A Review of International Models of Computer Science Teacher Education

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ABSTRACT

Throughout the world, Computer Science Education (CSE) has expanded exponentially over the past decade, focused on teaching primary and secondary students computing ideas and tools. To teach all these students computer science (CS), models for teacher preparation range from one and done professional learning workshops to full certificate and licensure programs. This report provides a landscape of how CS teachers are prepared academically in various countries and makes evidence-based recommendations for how teachers should be educated to develop knowledge and skill to teach computer science. It also discusses how to develop these knowledge systems while promoting instruction that is equitable and centers students in the classroom. We brought together a group of international computer science education scholars who have been engaged in teacher preparation. In addition to what knowledge teachers need to teach CS, we also focused on how the field is preparing teachers and the role of computer science in the design of technology tools to achieve goals while mitigating potential societal harms.

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CCS CONCEPTS

• **Social and professional topics → Computer science education**.

KEYWORDS

Computer Science Education, Teacher Education, Pre-service Teachers

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1 INTRODUCTION

The current efforts and enthusiasm around computer science (CS) education globally is encouraging [4, 35]; however, we need to build on this momentum and develop pathways for CS teachers to get certified to teach high quality CS instruction. In order to do so, we need to first understand K-12 teacher development and how teachers learn and develop CS content knowledge and pedagogical content knowledge [8]. However, we still lack an understanding of how teachers are being educated to be able to teach computer science. CS teacher preparation differs across and within countries ranging from short-term professional development workshops to undergraduate or postgraduate degree programs. Studies have shown that short-term professional development workshops have not been sufficient to build critical CS teacher knowledge and practices [47], yet that remains the primary model for training CS teachers, especially in the United States. To build K-12 CS teacher capacity, we need to design and develop certification programs that develop deep knowledge of CS content and how to teach that content to novice learners in primary and secondary schools.

Shulman (1986) described the critical importance of teachers' possession of both the knowledge of subject matter as well as knowledge of the ways to teach that subject matter (pedagogical content knowledge) [65]. For teachers to be able to teach CS, they need both CS content knowledge and CS pedagogical knowledge as absence of either of these knowledge components will likely result in ineffective teaching [27]. Furthermore, teaching presents unpredictable situations "demanding subtle judgments and agonizing decision" [66], which is even more true for CS instruction due to student-centered and multiple ways to problem solve [71]. A study in Ireland on CS teacher agentic decisions in achieving teacher agency and students achieving learner agency found that "the teachers believed they needed to know the content knowledge before they can delve into the pedagogical knowledge; separating the content and pedagogical knowledge." [63, p.9]. A related study on the challenge of teaching computer science with U.S. secondary teachers found that novice CS teachers struggle with content knowledge in particular with programming constructs as they have limited programming experience themselves [71]. Teachers in the study also reported that the student-centered nature of the CS work in the classroom made it difficult to keep all students engaged as well as challenges associated with the unique nature of how students approach the programming tasks. Sadik and colleagues found similar results through an examination of the Computer Science Teachers Association (CSTA) listserv and follow-up survey of 121 secondary U.S. computer science teachers [61]. The most common pedagogical need expressed by CS teachers was learning student-centered strategies for teaching CS and guiding students' understanding with the use of scaffolding and team-management strategies in CS classes.

Although relatively new in most countries, many teacher education programs have been created to prepare teachers to teach secondary CS. However, the lack of clarity around certifications and disparate requirements across jurisdictions produces challenges for teacher educators to create high-quality programs that address CS content knowledge and pedagogical content knowledge [67]. By understanding the variations and nuances around pathways for CS teaching certification and registration, we can begin to compare and contrast the design choices and how to best address knowledge teachers need to offer rigorous CS instruction.

At ITiCSE 2022, our working group "Models for Computer Science Teacher Preparation" explored these questions and identified how various European countries and certain states in the United States prepare secondary school CS teachers. In addition, we also reviewed the current recommended best practices around CS content and pedagogical content knowledge for teachers and how each of the working group participating members' home state/country addressed that knowledge. Specifically, the working group was guided by the following research questions:

(1) How are secondary computer science teachers prepared across the United States, Germany, Ireland, Spain, Netherlands, and New Zealand?
(2) How do teacher preparation programs address CS content and pedagogical content knowledge to prepare secondary CS teachers?
(3) What challenges do teacher preparation programs face while designing secondary CS teacher preparation programs?
(4) What recommendations do expert CS teacher preparation programs have to create high-quality secondary CS teacher preparation programs?

2 CS TEACHER PREPARATION AND KNOWLEDGE

Computer science teacher preparation varies widely from one country to another and even from one region to another within countries [16, 33]. A 2013 report by the Computer Science Teachers Association suggested that CS certification and licensure within the United States was deeply flawed and often required irrelevant information [22]. The latest State of CS Education report also shows that CS teacher certification is not uniform across states in the US [14]. At the same time, CS teachers face a number of challenges unique to teaching CS, such as being the only CS teachers in a school, which has important implications for how to support them through ongoing professional learning rather than single time-bound activities [71]. Furthermore, high school CS teachers often do not identify themselves as CS teachers with one their own backgrounds and certification in other subject areas contributing to the lack of professional identity [51].

In order to address these issues and develop teachers into knowledgeable, reflective, skillful and effective practitioners, we need to build programs that develop teachers' knowledge systems that are fundamental to the professional practice of teaching, including knowledge of student thinking and learning, and knowledge of subject matter [65]. Teaching is also dependent upon highly flexible access to organized systems of knowledge that requires teachers to make decisions in a complex, ill-structured, and dynamic classroom environment [28, 46]. Borko and Putnam [9] presented a framework for organizing teachers' knowledge and beliefs that included: a) general pedagogical knowledge and beliefs; b) subject matter knowledge and beliefs; and c) pedagogical content knowledge and beliefs. The general pedagogical knowledge and beliefs include teacher's knowledge and beliefs about teaching, learning, and learners that go beyond particular subjects and include knowledge and beliefs about classroom management, instructional strategies, and about learners, how they learn, and how that learning can be fostered by teaching. The subject matter knowledge includes knowledge facts, terms, and concepts of a discipline as well as knowledge of how disciplinary ideas are organized, how those ideas are connected to each other, and ways of thinking in the discipline. Finally, pedagogical content knowledge includes "the ways of representing and formulating the subject that make it comprehensible to others," and "an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" [65].

Within computer science education, the subject matter knowledge teachers need to teach CS varies widely dependent on the context and type of courses being taught, which range from basic introductory courses, such as Exploring Computer Science in the U.S. to programming intensive courses (such as Advanced Placement CS-A course). As such teachers need subject matter knowledge to cover a wide range of CS topics so they can help students develop conceptual understanding. In the United States, the ETS Praxis, Pearson, or other state level tests provide a broad overview of CS knowledge and competencies necessary for a secondary CS teacher within five areas: 1) understand and work with computer science concepts; 2) use algorithms and computational thinking; 3) work with code; 4) manipulate data, and 5) demonstrate knowledge of computing systems and networks [24]. These areas cover CS content knowledge teachers need to be effective.

A number of scholars have also discussed the kinds of knowledge CS teachers need to be successful and become effective at CS instruction (e.g., [25][70][30]). Hubwieser and colleagues [34] categorized the knowledge teachers need to teach computer science into two overarching categories: Fields of Pedagogical Operation and the Aspects of Teaching and Learning. Fields of Pedagogical Operation includes the phases of the process of teaching and learning in the classroom encompassed by three types of knowledge: 1) planning and design of learning situations, 2) reacting on student's demands during teaching processes, and 3) evaluation of teaching processes. Aspects of Teaching and Learning includes 14 other relevant pedagogical and content sub-categories, such as subject matter knowledge, curriculum, and lesson planning.

These efforts have largely focused on categorizing and measuring knowledge needed to teach CS, but we know little about whether and how teacher preparation programs engage their students in developing these knowledge components. While computer science across the globe has expanded over the last decade, the ways teachers are educated remains disparate within and across countries. This working group brought together CS teacher educators to shed light on models of teacher education and how teachers' knowledge to teach CS is developed within participants' home countries/states.

3 METHODOLOGY

3.1 Working Group Participants

CS teacher educators and CS education researchers from Ireland, Germany, the Netherlands, New Zealand, Spain, and the United States participated in the working group to get a broader perspective on how CS teachers are prepared across these countries. The United States participants came from Georgia, Indiana, Michigan, Ohio, and Texas. Each of the participants was currently involved in teacher education and had a deep understanding of the CS education landscape within their home country/state (see Figure 1). They all had several years of experience in educating CS teachers. Besides this level of experience, the participants were selected for regional reasons. Half of the experts were from the U.S., and half are from other countries. No two participants shared the same country/state to get a broad overview.

3.2 Data Collection and Analysis

In order to address our overarching question of how CS teacher knowledge is developed, we examined the various certification requirements and course standards across participating members' home countries/states.

In the first step, we collected initial ideas for CS teacher preparation from all participants. They addressed the following general questions/prompts:

- Describe the CS teacher preparation landscape and model in your country/state.
- What are the subject specifications and teacher knowledge requirements to teach CS?
- In your opinion and to the best of your knowledge, how do you prepare teachers to bring equitable and justice-oriented CS into their classrooms?
- In your country/state, how do you prepare teachers to bring new computational ideas (such as, artificial intelligence and machine learning) into their classrooms? Please details any new computational ideas you refer to, such as artificial intelligence and machine learning.

In order to better understand the design choices for teacher preparation that each of the jurisdictions made and the challenges they face, the working groups first worked in pairs using Stanford D-school design thinking process [1]. This design thinking process included five facets (Empathize, Define, Ideate, Prototype, and Test) and has previously been used to identity and address educational problems of practice [31]. The Empathize mindset involved developing a better understanding of each other's teacher preparation programs, building empathy for the issues that exist within those programs, and determining what can be leveraged to address the issues. The Define mode used the findings from the Empathize phase to help provide focus and frame the issues within teacher education programs that guided the design process. The Ideate phase of the design process allowed group members to focus on idea generation for CS teacher preparation and help them transition from identifying problems into exploring solutions. The Prototype mode shifted the focus from getting ideas from participants' head into the physical world using notes, sketches, etc., as they addressed issues and redesigned their partner's CS teacher preparation programs. Finally, the Testing mode engaged participants in sharing their redesigns with another dyad of participants, providing a chance to refine their solutions and, in some cases, provided opportunities to rethink what it means to educate CS teachers. This design process was flexible and participants spent two hours learning about various teacher preparation programs and implications for developing CS teacher knowledge. This design thinking activity provided participants with an opportunity to reflect with one another about CS teacher preparation programs within their own contexts as well as learn about another CS teacher preparation program. Specifically, participants were able to think about their own experiences in preparing CS teachers, important aspects of their CS teacher preparation, and their needs for preparing high quality CS teachers. This served as an important step for developing in-depth case studies for each jurisdiction that included recommendations for CS teacher preparation programs.

After the design thinking activity, participants spent time on developing case studies of CS teacher preparation within their jurisdictions. Using a template, each participants wrote about the background and history of CS education in their context, policy

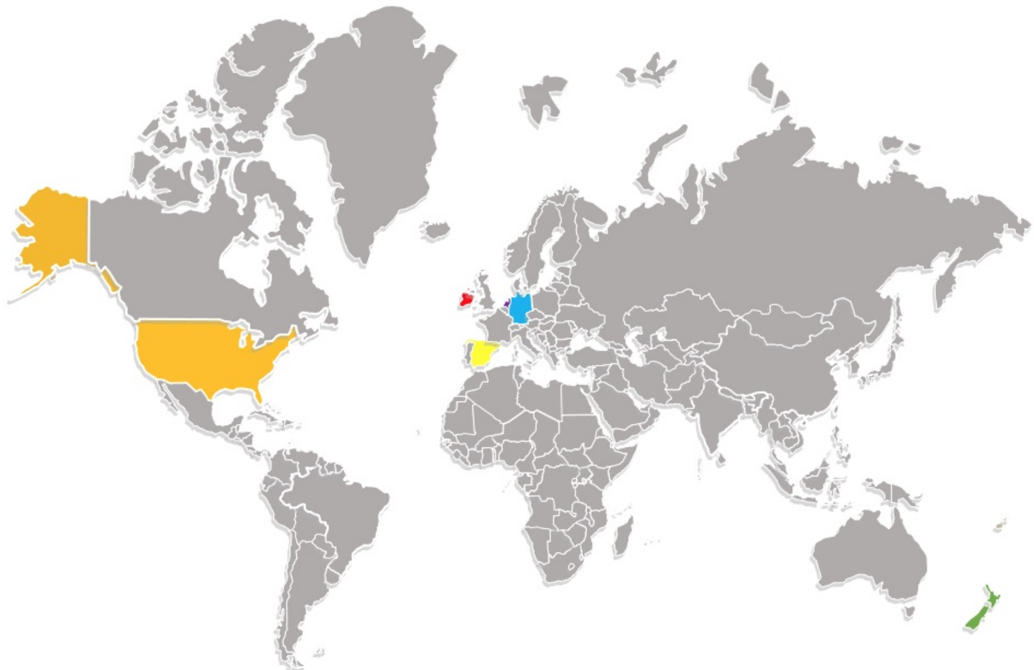

Figure 1: Home countries/states of the participants

requirements for licensing CS teachers, current status of CS teacher preparation, challenges their teacher preparation programs face, and recommendations to increase the number of well qualified CS teachers who can teach in ways that broadens participation in computing. Participants used documents from their home jurisdictions to develop their case studies. After individual case studies were written, all participants collaborated to identify pathways for teachers to gain CS content knowledge and pedagogical content knowledge. The outcomes are visualized with flowcharts in each individual case study.

3.3 CS Content and Pedagogical Content Knowledge

To address our second research question about the knowledge that secondary CS teachers need to teach CS, we separated content into CS content knowledge and pedagogical content knowledge (PCK) for teaching computing. For each type of knowledge, we started with well-established frameworks to compare to the working groups' teacher preparation programs. For CS content knowledge, our starting framework was the K12 CS Framework (k12cs.org) for secondary school (i.e., grade 9-12 in the framework, ages 14-18). For PCK, our starting framework was the Hubwieser et al. PCK framework for CS [34]. Both frameworks were chosen due to their generality and distribution in the community. The purpose of the working group was not to validate or extend the frameworks but to describe the different approaches throughout the participating countries or states. In addition, the working group worked as a whole to align whether and how each jurisdiction developed teachers' content knowledge and PCK. Thus, case studies and discussions were structured based on these frameworks and no inter-rater rating was conducted.

3.3.1 CS Content Knowledge. As a starting point for examining the CS content that teachers need to know, we compared the content included in the working group members' programs to the K12CS framework. The K12CS framework was developed in 2016 with a group of over 25 writers who included CS teachers, CS education faculty, and CS education advocates in the United States. In addition to the writers, the project also had several support staff and over 25 advisors also worked on the project (see Table 1).

The framework is not intended to be a set of standards and instead was intended to provide guidance as individual U.S. states developed standards for CS education at the primary and secondary level. Given the framework provides computer science concepts and practices students need to know, we believe that teachers also need an in-depth knowledge of the same concepts. As such, we used the framework to categorize knowledge that CS teachers need to provide high-quality CS education for their students. Secondary teachers typically learn university-level concepts in the discipline that they teach (e.g., science teachers take university-level science courses), and this depth of knowledge is achieved in some of the programs explored in the working group, especially European programs, but not in all programs. The case studies describe the depth of CS content knowledge taught in the programs.

Table 1: CS Content Knowledge for Secondary Schools in the K12CS Framework (k12cs.org).

Computing Systems
Devices - Computing devices are often integrated with other systems, including biological, mechanical, and social systems. These devices can share data with one another. The usability, dependability, security, and accessibility of these devices, and the systems they are integrated with, are important considerations in their design as they evolve.
Hardware and Software - Levels of interaction exist between the hardware, software, and user of a computing system. The most common levels of software that a user interacts with include system software and applications. System software controls the flow of information between hardware components used for input, output, storage, and processing.
Troubleshooting - Troubleshooting complex problems involves the use of multiple sources when researching, evaluating, and implementing potential solutions. Troubleshooting also relies on experience, such as when people recognize that a problem is similar to one they have seen before or adapt solutions that have worked in the past.
Algorithms and Programming
Algorithms - People evaluate and select algorithms based on performance, reusability, and ease of implementation. Knowledge of common algorithms improves how people develop software, secure data, and store information. Variables (Var) - Data structures are used to manage program complexity. Programmers choose data structures based on functionality, storage, and performance tradeoffs.
Control - Programmers consider tradeoffs related to implementation, readability, and program performance when selecting and combining control structures.
Modularity - Complex programs are designed as systems of interacting modules, each with a specific role, coordinating for a common overall purpose. These modules can be procedures within a program; combinations of data and procedures; or independent, but interrelated, programs. Modules allow for better management of complex tasks.
Program Development - Diverse teams can develop programs with a broad impact through careful review and by drawing on the strengths of members in different roles. Design decisions often involve tradeoffs. The development of complex programs is aided by resources such as libraries and tools to edit and manage parts of the program. Systematic analysis is critical for identifying the effects of lingering bugs.
Networks and the Internet
Network Communication and Organization - Network topology is determined, in part, by how many devices can be supported. Each device is assigned an address that uniquely identifies it on the network. The scalability and reliability of the Internet are enabled by the hierarchy and redundancy in networks.
Cybersecurity - Network security depends on a combination of hardware, software, and practices that control access to data and systems. The needs of users and the sensitivity of data determine the level of security implemented.
Data and Analysis
Data Collection - Data is constantly collected or generated through automated processes that are not always evident, raising privacy concerns. The different collection methods and tools that are used influence the amount and quality of the data that is observed and recorded.
Data Storage - Data can be composed of multiple data elements that relate to one another. For example, population data may contain information about age, gender, and height. People make choices about how data elements are organized and where data is stored. These choices affect cost, speed, reliability, accessibility, privacy, and integrity.
Visualization and Transformation - People transform, generalize, simplify, and present large data sets in different ways to influence how other people interpret and understand the underlying information. Examples include visualization, aggregation, rearrangement, and application of mathematical operations.
Inference and Models - The accuracy of predictions or inferences depends upon the limitations of the computer model and the data the model is built upon. The amount, quality, and diversity of data and the features chosen can affect the quality of a model and ability to understand a system. Predictions or inferences are tested to validate models.
Impacts of Computing
Culture - The design and use of computing technologies and artifacts can improve, worsen, or maintain inequitable access to information and opportunities.
Social Interactions - Many aspects of society, especially careers, have been affected by the degree of communication afforded by computing. The increased connectivity between people in different cultures and in different career fields has changed the nature and content of many careers.
Safety, Law, and Ethics - Laws govern many aspects of computing, such as privacy, data, property, information, and identity. These laws can have beneficial and harmful effects, such as expediting or delaying advancements in computing and protecting or infringing upon people's rights. International differences in laws and ethics have implications for computing.

3.3.2 CS Pedagogical Content Knowledge. We used the framework of Hubwieser et al. [34] as a starting point for providing an overview on the pedagogical content knowledge of CS teachers. In that model, aspects of teaching and learning (ATL) and fields of pedagogical orientation (FPO) are presented. They were derived from a broad literature review of general education resources and computer science education literature along with sources from related didactics such as physics and mathematics. Table 2 provides a short explanation of each category. Similar to the content knowledge, the working group participants categorized whether each of the programs addressed teachers' CS-PCK.

4 CASE STUDIES

To get a sense of some of the different approaches for educating CS teachers, case studies were collected from all participants. The case studies describe the contextual background and current landscape for CS teacher preparation in each country and state, including specific teacher education requirements and policies. The case studies were used to showcase how each jurisdiction develops CS teacher knowledge in their context as well as to categorize CS content knowledge and CS PCK across programs from participating countries and U.S. states. The case studies are presented in alphabetical order in the following subsections.

4.1 Germany/Bavaria

4.1.1 Background.
Bavaria is one of the 16 federal states in Germany. With a population of around 13 million people, it has the second-highest population among the states. This includes around 1.2 million students in secondary education distributed in around 2000 secondary schools (grammar, secondary, middle, and vocational). There are 1200 CS teachers in grammar and secondary schools. The number of teachers with a standalone CS education is not published [2].

General Teacher Education system. In Germany, the federal states are responsible for all educational purposes, including teacher preparation. Nevertheless, there is a standard system in all states. The teacher preparation is divided into three parts. The first part takes place at universities or educational universities. Here, the three knowledge areas of Shulman [65] are in focus; content knowledge, pedagogical content knowledge, and pedagogical knowledge. This part usually lasts between 3.5 and 4.5 years. Depending on the state, the study programs end with a Bachelor/Master degree or a state-specific exam. In general, there are no fees for going to university in Germany; however, the system is selective. The type of secondary school the students come from is crucial for how easy it is to gain matriculation standards to access university. There is a direct pathway for grammar schools, whereas, for the other secondary schools, the pathway to the computer-science teacher programs is more complicated.

The second part of teacher preparation takes place in special schools and usually lasts two years, ending with a state examination in most states. Here, the teachers teach on their own, supervised by experienced teachers. The focus of this phase is on the practical issues of teaching, such as classroom management, formative assessment, etc.

Table 2: Pedagogical Content Knowledge Framework for Teaching Computer Science

Learning content The learning content includes multiple representations of content, category systems for learning content. Furthermore knowledge about specific school-related content along with selection and justification abilities. Additionally, didactical (re-)construction of content knowledge is part of this category.
School subject Knowledge about the school subjects represents the definition and the knowledge about computer science education and the relationship of the subject Computer Science to other subjects. Besides Objectives the legitimacy and relevance of the subject is included.
Curricula and standards Teachers have to know about curriculum development, the relation of CS to other subjects, the approach and structure of the current curriculum, and examples of current curricula. Furthermore, they have to know about the selection and commitment of the curricula's content.
Objectives of lessons Teachers should be able to focus on educational standards, competencies, and learning objectives.
Extracurricular activities The category of extracurricular activities includes external collaborations and contests.
Science Teachers have to gain knowledge on the subject discipline, computer science education as a science, and the relationship between teaching of the subject and the subject itself.
Teaching methods In the category of teaching methods, organizational arrangements and methodological principles are collected. Moreover, teachers have to know about subject-specific teaching methods.
Subject-specific teaching concepts Teachers have to know about introductory lessons, programming classes, and historical approaches for computer science education.
Specific teaching elements Specific teaching elements in computer science are related to lab-based teaching, experiments, and tasks and assignments.
Media and educational material CS media and education material includes the application of hardware and software, textbooks, and unplugged media.
Heterogeneity in context of subject-specific learning Handling heterogeneity is crucial in computer science education. Though, there must be knowledge about heterogeneity issues regarding age, gender, ethical background, family socialization, and disabilities.
Student cognition The category of student cognition includes general subject-related cognitive aspects, individual learning diagnostics, as well as performance evaluation and assessment. Furthermore, cognitive activation belongs to this category.
Teacher' perspective CS teachers have to gain knowledge about collaboration opportunities, core tasks of teaching, motivation, and the teaching experience. Furthermore, knowledge about qualification and in-service training is crucial.
School development School development includes besides policies, quality management, and school profiles.
Educational system Knowledge about the educational system is about school types, enrollment, and organizational aspects of the subject itself.

The third part involved in-service professional development programs that are organized differently throughout the states. These programs focus on preparing in-service teachers to address specific aspects of teaching CS.

Recent History. The history of computer science teacher programs in Bavaria starts with the decision to make it a mandatory subject in grammar schools (grades five to thirteen) [32]. Of course, there were CS teacher programs before, but with this change in curricula, the need for qualified CS teachers increased significantly. As a result, in 2001, universities established the first program to qualify CS teachers. As in the follow-up program SIGNAL, number of classes teachers taught was reduced, so they had time off to attend university courses.

Additionally, the regular programs for undergraduates were adapted to the new curricula. The new subject started in the fall of 2003. Addressing the shortage, a variable program was established as a follow-up [7] that allowed teachers to attend blended-learning classes [58] on their own time. However, teachers were not give a reduction in teaching. Nevertheless, around 200 teachers were educated by this program till its end in 2021. With a switch back to nine years of grammar school, a mandatory year of computer science was introduced to the grammar school curriculum. Together with an increase of CS education in the other school types, a huge amount of new teachers were needed. Therefore, another CS teacher education program was established. For grammar school and secondary school again, with a reduction of teaching. For middle schools, there was no special program but an initiative where every school sent one teacher to a PD program lasting a couple of weeks and then disseminated the knowledge to their colleagues in schools.

4.1.2 Current Status.

In Bavaria, teacher preparation in the first part takes place only at universities. For grammar schools and secondary schools, teacher-students choose two subjects. For CS, the second subject can be Mathematics, Physics, English as a foreign language, Economics, Biology, or Chemistry. Middle school teachers have to teach all subjects, which means teacher-students have mandatory subjects like German or Mathematics and choose from other subjects, including CS. At the moment, there is no CS in primary schools in Bavaria, so there is no teacher preparation for those teacher students in CS. Pre-service teachers for vocational schools can choose CS as their teaching supplement and then have to take CS classes for their Bachelor/Masters degree. The second part of the teacher preparation program lasts two years in Bavaria. The professional development programs are mainly organized by an institution of the federal ministry for education. Nevertheless, universities have their programs, and during the last few years, more and more commercial programs have been available.

Depending on the school type, the amount of CS classes differs. For grammar school, the pre-service teachers have to take courses with a workload of 105 credits in the European Credit Transfer and Accumulation System (ECTS). Here, one ECTS equals a workload of 30h. The 105 ECTS include at least 8 ECTS in special computer science education classes. Additionally, they have another 105 ECTS in their second subject and 60 ECTS for practical courses and general pedagogy. For secondary schools, the workload is only 72 ECTS per subject and 66 ECTS on practical courses or general pedagogy. Middle school pre-service teachers have to take classes with 66 ECTS in CS.

There is a state-wide examination twice a year for the different school types. The pre-service teachers have to pass three written assessments with the general topics of algorithm and data structures, theoretical computer science, and databases, together with software engineering and computer science education. For grammar school, universities have to take care of technical computer science and a software-project. For the other school type, only the software project is mandatory. In addition to the nationwide standards for teacher education, there is a statewide curriculum for computer science teachers, which is the basis for the examination (translated from German):

(1) theoretical computer science
(2) database systems
(3) software technology
(4) Computer science education
  a) Basics of subject-related teaching and learning
  b) Conception, design, and evaluation of specialized teaching

The in-service programs need to cover the content above as well, but they are synchronized throughout the state and therefore have a common set of classes (see Figure 2).

4.1.3 Teacher preparation requirements and policy.

To become a computer science teacher in Bavaria, there are two pathways (see Figure 3). First, there is an undergraduate program including general teaching studies as well as up to one-third of computer science content knowledge. In the end, there is a mandatory state examination that is necessary to teach Computer Science at secondary schools. The second way to the state examination is for in-service teachers attending special professional development programs. Nevertheless, because of the teacher shortage, there are emergency programs for non-teachers to get a license for teaching based on their experience in CS.

4.1.4 Diversity, Equity, and Inclusion (DEI).

Teacher students have to take classes in School Pedagogy, where inclusive education is a part. Furthermore, students can take seminar classes on an elective basis. Furthermore, handling heterogeneity in CS is one of the most challenging and important aspects of computer science education. Nevertheless, it is not addressed in the core curriculum, and so it is up to the universities to integrate it into computer science education lectures dealing with a wide understanding of inclusive education.

4.1.5 Emerging Computing Topics.

The answer to this question is twofold. For the integration of new topics into the curriculum, the federal ministry of education is in charge. This process includes several groups like scientists, experienced teachers, and others that inform how the university curricula are adapted to the new topics. Furthermore, there is a state institution for professional development offering in-service PD programs on a daily or weekly basis. On the other hand, universities offer PD programs on their own for topics they want to introduce to in-service teachers. Currently, in Bavaria, artificial intelligence (AI) is included in the new grammar school curriculum for CS. The focus in the first year is on machine learning, and in the second year on classic symbolic AI. All the Bavarian universities offer PD programs for AI to qualify the around 1200 CS teachers.

4.1.6 Challenges.

With the introduction of a mandatory computer science subject for all students in all school types, there is a shortage of teachers. The low number of graduating teachers does not meet the number of CS teachers needed. So further PD programs for in-service teachers will be necessary for the future. However, that also leads to teachers teaching to the test to cope with the tremendous amount of CS knowledge students need to gain.

4.2 Ireland

4.2.1 Background.

Several studies and a 2016 publication by the Irish Department of Education (DES) titled 'STEM Education in the Irish School System' [23] identified the necessity to introduce Computer Science as a Senior Cycle curriculum subject [17]. Then Minister for Education announced that the National Council for Curriculum and Assessment (NCCA) develop a subject titled 'Computer Science' and in March 2016 the designers selected and development of the specification began. The Leaving Certificate Computer Science (LCCS) specification has the potential to develop active creators and producers, rather than passive consumers and users of technology.

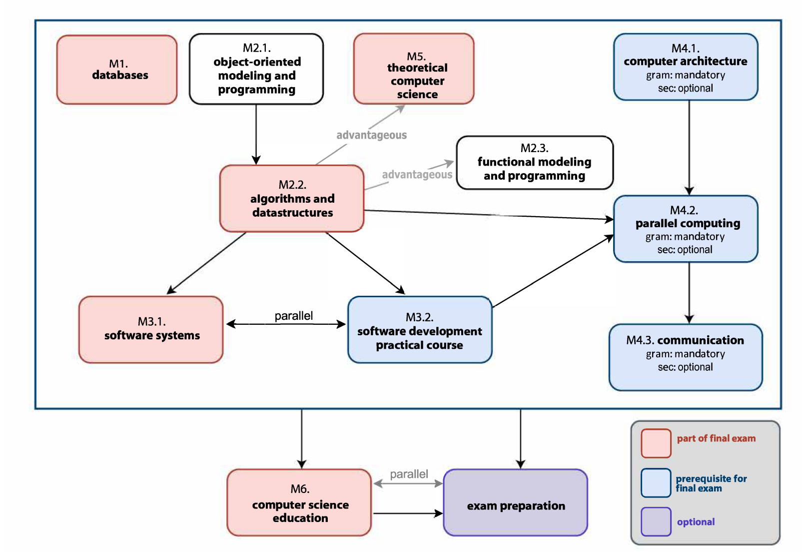

Figure 2: Overview of modules for the in-service program in Bavaria

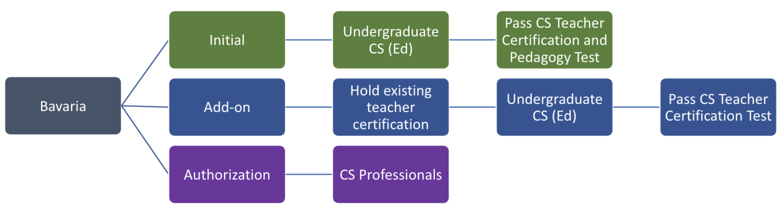

Figure 3: Pathways to CS teacher preparation in Bavaria

LCCS may offer potential opportunities for enhanced inclusion and equity, providing students with an understanding of CS. Like many other jurisdictions, expertise in STEM, especially CS, is seen as central in supporting the innovation and future prosperity of Ireland, particularly in the wider context of the Digital Transformation [16]. Therefore, the launch of a Computer Science specification in upper secondary schools in Ireland in 2018, as an examinable subject for Senior Cycle (upper second level: 16-18 years old) was warmly welcomed [15]. The subject was made available for students, contingent on whether a student's school was offering CS as an exam subject (see Figure 4).

There are a number of new teacher education undergraduate degree programs that have been introduced to prepare CS teachers. These teacher preparation programs will graduate their first cohort of CS teachers in 2023 at the earliest.

4.2.2 *Current status.*

The total student post-primary population in Ireland in 2021 was 379,184 with 706 students completing the LCCS examination, the subject being available in 72 schools. The percentage gender breakdown for Leaving Certificate Computer Science higher level was 72.2 Male and 27.8 Female in 2021 [42]. As a relatively new subject the Leaving Certificate Computer Science was first piloted in 2018 with 40 schools (Phase 1) equating to 739 students studying the subject 2020 [42]. Phase 2 roll-out of the subject involved 52 schools and in Phase 3 there were 48 schools. The Professional Development Service for Teachers (PDST) engaged with 140 schools upskilling teachers to teach CS. There are a number of new teacher education undergraduate degree programs that have been introduced to prepare CS teachers. These pre-service teacher preparation programs will graduate their first cohort of CS teachers in 2023 at the earliest. There are currently four Teaching Council accredited undergraduate concurrent CS initial teacher education programs available at universities in Ireland (see Table 3).

The content of CS subject requirements according to the Teaching Council stipulates that the teacher must demonstrate evidence of 60 ECTS (The European Credit Transfer System) in CS. ECTS is a credit system to modules and programs. Each ECTS corresponds to 20 learning hours, to include lecture, tutorial as well as independent study time.) The 60 ECTS in CS must include the study of all the following essential areas: 1) Software Engineering and Project Management; 2) Programming (including algorithms and data structures); and 3) Computer Systems (including hardware or architecture). The candidate should also demonstrate evidence of a minimum of two of the following areas: 4) Web development; 5)

Strand 1: Practices and principles	Strand 2: Core concepts	Strand 3: Computer science in practice
‣ Computers and society ‣ Computational thinking ‣ Design and development	‣ Abstraction ‣ Algorithms ‣ Computer systems ‣ Data ‣ Evaluation/Testing	‣ Applied learning task 1 - Interactive information systems ‣ Applied learning task 2 - Analytics ‣ Applied learning task 3 - Modelling and simulation ‣ Applied learning task 4 - Embedded systems

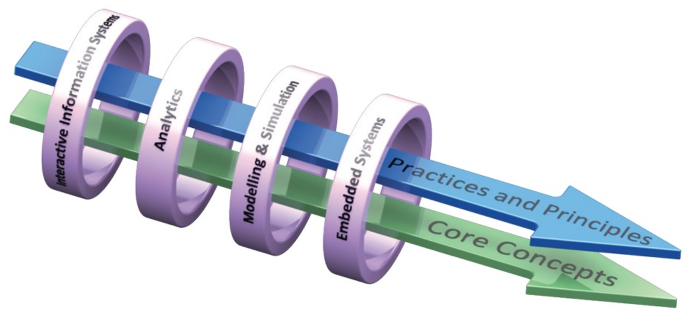

Figure 4: Computer Science Specification in Ireland

Table 3: University, teacher education providers with accredited CS programs

Educational Institution	Course Title
University of Galway	Bachelor of Education (Computer Science and Mathematical Studies)
University of Limerick	Bachelor of Science with Mathematics and Computer Science
Maynooth University	Masters of Science in Mathematics Education
University College Dublin	MSc in Mathematics and Science Education

Animation/ games/ multimedia development; 6) App development; 7) Robotics; 8) Embedded systems; 9) Modelling/ simulation; 10) Data analysis; 11) Databases; 12) Machine learning/AI [18].

4.2.3 Teacher preparation requirements and policy.
Education in Ireland is centralized and the Teaching Council accredit all teacher education programs. Irish initial teacher education was significantly altered or remodelled following proposals by an international review panel in 2012, [62] where they firmly declared that teacher education training should be research-driven within a University setting. The requirements for accreditation of a teacher education program specify details such as the program entry requirements, partnership model for school placement, staff-student ratios and curriculum content [18]. The Teaching Council also maintain the subject requirements criteria [19] and is the statutory body also responsible for maintaining the register of qualified teachers nationally. There are two approaches to becoming a CS teacher in Ireland. Firstly, at undergraduate entry, a four year concurrent initial teacher education program designed to address an identified need within Irish education for specific subject discipline. The concurrent model has several advantages. Firstly in providing a gentler route into the teaching profession than the Professional Masters course. Secondly, it provides a speedier route into teaching for those who wish to pursue their vocation. The concurrent model also ensures the combined study of academic subjects and craft knowledge/skills enabling a special synergy of the practical and professional dimensions of the profession. Within a concurrent model of teacher education there are many links across modules, established through content and assessment. ITE concurrent program are designed in a similar format with four intersecting elements - content knowledge, pedagogical knowledge, pedagogical content knowledge, and professional practice present. The graduate route is an alternative, for the purposes of registration as a post-primary teacher, whereby candidates complete a full-time two year Professional Masters in Education (PME) program. Student teachers develop their pedagogical knowledge, as well subject methodology knowledge to teach the post-primary curriculum subjects, such as CS.

4.2.4 Diversity, Equity, and Inclusion (DEI).
As stated previously all teacher education programs in Ireland are accredited by the Teaching Council [20]. Interestingly 'diversity' in the Teaching Council documentation refers to Diversity of Program Content (Section 1.1.6 Integration and Diversity of Program Content, [20]). Race, gender, and equity may be addressed in the global citizenship and inclusive education but are not explicitly stated as requirements. A range of concepts covered within global citizenship education (GCE) focus on key theoretical concepts and the broader value of GCE within education and society. The United Nations sustainable development goals are often utilized as a means of framing GCE focused discussions, which in turn is incorporated

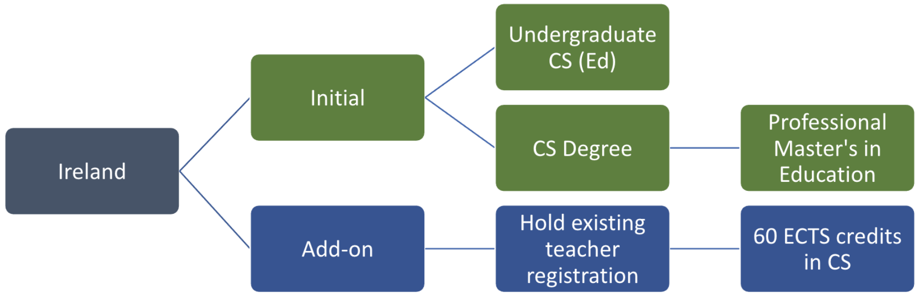

Figure 5: Pathways to CS teacher preparation in Ireland

within school placement and practice. Inclusive Teaching is often interdisciplinary combining sociological and psychological perspectives. Its central objective is to inspire and empower pre-service teachers to develop a "humanising pedagogy" that is grounded in social justice, anti-ableist, equity-based principles, through a number of pathways. The Teaching Council define inclusive education as "any aspect of teachers' learning aimed at improving their capacity to address and respond to the diversity of learners' needs; to enable their participation in learning; and remove barriers to education through the accommodation and provision of appropriate structures and arrangements to enable each learner to achieve the maximum benefit from his/her attendance at school." [20, p.4].

4.2.5 *Emerging computing topics.*

The Teaching Council update and publish subject requirements for teacher registration. Nevertheless subject requirements were published in 2014 and revised in 2020 [19].

4.2.6 *Challenges.*

The main barriers to access and the growth of CS remain where no coding or computer studies are being offered to students; and where there are no teachers with the skill set among the school staff. Also there is a general perception that other 'new' subjects such as Physical Education, Politics & Society are easier to implement in schools. CS is available in a school in each county, except counties Longford and Leitrim where no school is offering CS at secondary level [43]. Computational thinking and coding are not currently a formal part of the Irish primary curriculum however a new primary curriculum is currently in draft format, and "there are demands to include new aspects of learning in the curriculum such as coding and computational thinking" [48, p.2]. Without a presence in the primary curriculum, it remains a difficulty to encourage young people study the subject at secondary school.

There are a range of issues and challenges that are emerging for CS teacher preparation in Ireland. In acknowledging and tackling the tightly intertwined issues of gender balance, equity and inclusion, there is a necessity for all students attending primary school to have the opportunity to develop computational thinking, coding, and CS skills.

In strengthening the acceptance of CS as a foundational competence for all, enabling children, and young people to become active participants in a digital economy, there is a necessity for systemic roll-out adopting a holistic approach to the introduction of computing competencies in formal education in an equitable manner. It is well known that a knowledgeable, competent, and well-prepared teacher is vital to student learning [12, 60] and this is also true for CS education. Yet Ireland has only 16 CS teachers on the Teaching Council register [43]. This shortage of qualified teachers is a barrier to providing all students with equitable access to CS education, similarly, experienced in other jurisdictions. It has been stressed that initial teacher education and teacher professional development need to prepare student teachers to teach CS to cohorts with diverse ethnicities, socioeconomic backgrounds, and genders [10]. In sustaining a systemic roll-out and a holistic approach to computing competencies within the Irish education system the provision of professional development for the upskilling of teacher's pedagogical content knowledge in computing and computational thinking competencies is crucial [63].

4.3 The Netherlands

4.3.1 *Background.*

Computer science was first introduced as an elective secondary education in the Netherlands in 1998 [5]. Since then, it is not a mandatory course and due to the lack of teachers in the Netherlands CS is not even offered as an elective in a number of high schools. Moreover, due to experienced computer science teachers retiring and the profession of the teacher in the Netherlands not being an attractive choice for potential recruits, this deficit is expected to grow in the next years.

Prospective CS teachers in the Netherlands who wish to teach in upper secondary education need a master's equivalent degree in CSE. This degree prepares them to teach CS in secondary education for senior general secondary education (HAVO) and pre-university education (VWO), both from grade seven (typically for 12-year-old students and last for five and six years respectively).

According to Statista [1], the estimation for high school students enrolled in the Netherlands, a country with a population of around 17 million people in 2021, is 934,200.

4.3.2 *Current Status.*

Currently, there are programs for teacher preparation across the

[1]https://www.statista.com/

country that strive to equip prospective computer science teachers with the essential skills to teach CS as a subject in high schools. There are programs at Utrecht University, Eindhoven University, Groningen University, Free University of Amsterdam, Leiden University, University of Twente among other universities. There are also programs for lateral entry into the teaching profession. Then, prospective teachers must first find a school (board) or an MBO (secondary vocational education) institution where they can be employed and follow the program. To see if they are suitable for it they will have to participate in an aptitude test.

4.3.3 Teacher preparation requirements and policy.

A Bachelor's degree consists of 3 years of study (180 ECTS in total). The equivalent of one study credit (EC) is 28 hours of work and includes time spent during lectures and labs but also self-study and working on assignments, etc. Traditionally, to be able to teach CS in upper high school, teachers need to acquire a master's degree in education. The master's program's duration varies and is usually for 2 years but there are variations from one year to two years program. The typical requirement for entering a two years master's program is a bachelor's degree in CS. The two-year teacher preparation master's programs for CSE usually consist of deepening content knowledge in CS (in the first year) (60 EC in CS-related courses/projects) and following the education program in teaching (60EC). The requirements for entering a one-year university master's program include the following criteria: First, students need to possess at least 120 EC of the subject study distributed across all core CS domains (discrete mathematics, programming and algorithms, information systems, hardware and networks, fundamentals of CS) at the start of the one-year Master's Degree for prospective teachers in Computer Science. All CS teacher candidates that:

- possess a Bachelor's degree and a Master's degree in Computer Science from a Dutch university are directly eligible for admission to the program
- possess a Ph.D. in Computer Science are directly eligible for admission to the program
- have obtained 120 EC in computer science, distributed across all core domains, through a bachelor's or doctoral program, and candidates who hold a master's degree or a combination of a bachelor's and master's degree are further assessed during their application

In the latter case, when a teacher candidate in CS has a subject knowledge deficiency, a maximum of 15 EC in subject deficiencies may be eliminated as a graduation requirement during the teacher training program. If there are more than 15 EC in content-knowledge deficiencies, the candidates should obtain these before the start of the master's program through an individually determined transition track. Only with a course deficiency of 60 EC or less, is a switch program possible. Inf4all [2] for example, offers switching programs for aspiring CS teachers. The program offers eight 6 EC courses that can be used to overcome the most common deficiencies in computer science. The program is easily combined with a study or a job and if candidates are (conditionally) admitted to a university teacher training program they can take the inf4all courses for free.

The master's program includes courses in subject-specific didactics of CS and courses common to all teachers studying the Science Education and Communication master's program or similar master's programs in CSE.

A minor in education when studying CS can also allow an individual to teach in lower secondary education. With a second degree, individuals may teach the lower grades of HAVO/VWO (typically teaching students 12-15 years old), VMBO (Pre-vocational secondary education, all grades: 1-4, typically teaching students 12-16), and MBO (secondary vocational education). CS in the Netherlands is usually in upper secondary education therefore you normally need a first degree.

4.3.4 Diversity, Equity, and Inclusion (DEI).

At the Master's level, part of the curriculum addresses societal issues in education through mandatory courses. There are also elective courses related to DEI including special education practice and the course "Issues and Theories in Science Education and Communication" where topics like diversity, inclusion, and accessibility, are addressed. During the master's program, prospective students are called to design and implement learning activities that are inclusive and empower diverse individuals considering different needs and abilities. During lectures and teaching instruction design, societal issues are often used for examples, e.g., in the case of AI and ML, using biased data in favor or against an individual, group, or characteristic that is considered to be unfair such as race, age, gender, disability, ethnicity, etc. Prospective and in-service teachers also have opportunities to enroll in professional development sessions with themes like inclusion, UDL Universal design for learning, etc. However, there is no formal requirement for lecturers to address such issues during teacher preparation.

4.3.5 Emerging Computing Topics.

Our program focuses on equipping teachers with the necessary knowledge and skills to teach core concepts of computer science in their classrooms. However, emerging computing topics like AI and machine learning are only covered in elective courses. There are possibilities for professional development workshops/master classes that could accommodate the introduction of similar emerging computing topics. Curricula reforms in CS are happening every few years and aim at bringing new computational ideas to the classroom. For example, in the Dutch informatics curricula and curricula.nu reform the importance of CT and digital literacy are emphasized. Universities and other institutions that provide teacher preparation programs and professional development opportunities in CSE through seminars and master classes can potentially address emerging computing topics. Unfortunately, these programs are elective and sometimes teachers need to pay fees that might not always be covered by schools. Several organizations also offer learning and teaching material on new emerging topics in technology and computing among other things (e.g., informatica-actief [3], Fundament Informatica [4], SLO[5].

[2]https://beta4all.nl/inf4all-programma/

[3]https://www.informatica-actief.nl/

[4]https://fundament-online.nl

[5]https://https://www.slo.nl/

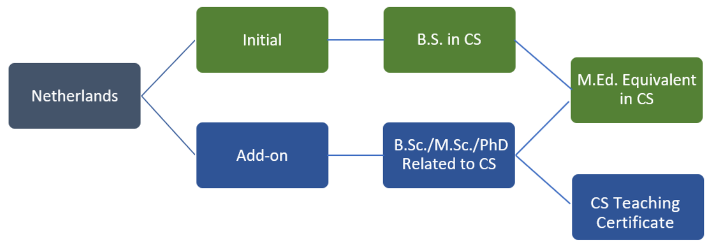

Figure 6: Pathways to CS teacher preparation in Netherlands

4.3.6 *Challenges.*

Even though digital literacy and computational thinking are stressed in curricula reforms and there are increasing efforts to pose them as integral parts in the Dutch curricula, CS is still not a mandatory subject and in some schools is not even offered as an elective. Computer science education is still relatively new in Dutch curricula in comparison to other subjects that have been taught for many decades. There are calls everywhere for introducing students to computing with well-trained teachers that can efficiently address issues in computer science education like equity, inclusion, and participation/representation in computing. A major challenge in the Netherlands is the lack of STEM teachers in general, especially the ones for CS. At the same time, issues of under-representation and lack of role models in CS as well as barriers related to accessibility and lack of support might be major reasons for this. Recently, many teachers quit their jobs because of the Covid pandemic, and several often complain about the extremely high workload, especially when covering for colleagues on sick leave or due to the lack of teachers.

4.4 New Zealand

4.4.1 *Background.*

In New Zealand, there are 377 secondary schools. The majority of these schools are state schools which teach the New Zealand curriculum, or Te Kura Kaupapa Māori (Māori-language immersion) state schools where the teaching is in Te Reo Māori (the language of Māori) and follow Te Marautanga o Aotearoa (the curriculum for Māori-medium education). State-integrated secondary schools are part of the state system; however, they used to be private schools and often have their own special charter (usually a religious belief). There are also private schools where there are fees for the students to attend. All secondary schools in New Zealand cater to students from years 9-13 (ages 13-18) or years 7-13 (11-18). There are 25,000 secondary teachers in total, and in 2020, there were 815 graduating secondary school teachers in New Zealand. It is difficult to find data on graduating computer science secondary teachers.

In New Zealand, computing standards were introduced in 2011 under five topics: (1) Digital Information (managing information via digital tools and systems); (2) Digital Infrastructure (hardware and networks); (3) Digital media (video, audio, website layout/design), (4) Electronics, and (5) Programming and Computer Science (designing and implementing programs). The five areas had learning objectives corresponding to the required knowledge and skills in that area[6]. The objectives were further broken down into levels 6, 7, and 8 of the New Zealand Curriculum (NZC) aligning with the last three years of secondary school (years 11-13 or ages 16-18).

4.4.2 *Current Status.*

In 2018, the computing standards were updated when Computational Thinking (CT) and Designing and Developing Digital Outcomes (DDDO) for digital technologies was introduced into the NZC and Te Marautanga o Aotearoa for both primary and secondary schools and Te Kura Kaupapa Māori. In Te Marautanga o Aotearoa, the curriculum (Hangarau Matahiko) is not a direct translation of the English version, but addresses CT/DDDO principles for Māori medium contexts. The updated technology learning area emphasizes creation, problem-solving and innovation rather than solely using digital technology to support learning [41].

Learning objectives from 2011 were also updated as progress outcomes according to the curriculum learning levels (see Figure 7). The updated technology learning area involves teachers learning the content and teaching students network architecture, complex electronics environments and embedded systems, interrelated computing devices, hardware and applications, digital information systems, user experience design, complex management of digital information, and creative digital media. For example, the final digital technology progress outcome for computational thinking for students in their last year of school is called Progress Outcome 8 DTCT with the goal of "within authentic contexts and taking account of end-users, students evaluate concepts in digital technologies (for example, formal languages, network communication protocols, artificial intelligence, graphics and visual computing, big data, social algorithms) in relation to how key mechanisms underpin them and how they are applied in different scenarios when developing real world applications"[36].

In addition, teachers also need to understand and teach content to support the progress outcomes for designing and developing digital outcomes (see Figure 8). For the same age group, Designing and Developing Digital Outcomes Progress Outcome 6 requires students to "independently investigate a specialized digital technologies area and propose possible solutions to issues they identify. They work independently or within collaborative, cross-functional teams to apply an iterative development process to plan, design, develop, test and create quality, fit-for-purpose digital outcomes that enable their solutions, synthesizing relevant social, ethical and end-user considerations as they develop digital content" [38].

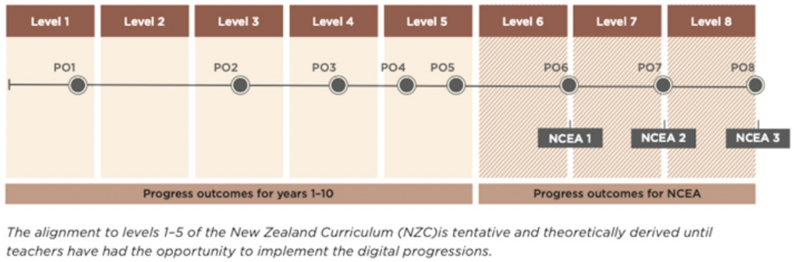

Figure 7: Computational Thinking for Digital Technologies [36]

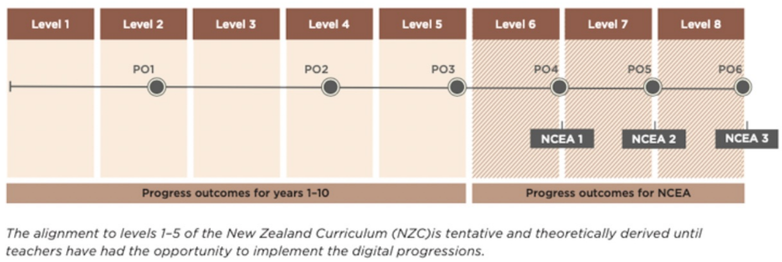

Figure 8: Designing and Developing Digital Outcomes [38]

In addition to the updated technology learning area for years 1-13, the Review of Achievement Standards (RAS) is currently piloting new NCEA (National Certificates of Educational Achievement) level one achievement standards aligning with the new technology learning area. The new standards will be implemented in 2023 (Level 1), 2024 (Level 2) and 2025 (Level 3). The existing achievement standards (used for this case study) remain current and continue to be available for use in secondary schools until they are replaced by the new standards from 2023.

4.4.3 *Teacher preparation requirements and policy.*

The following section outlines the qualifications required to become a secondary school teacher through universities in New Zealand and provides examples of courses specifically for teachers of digital technology. The University of Otago has a Master of Teaching and Learning (MTchgLn) degree. This postgraduate (Level 9) qualification is aimed at people with a university undergraduate degree who want to become secondary school teachers, and for admission, applicants need an above B average in their final undergraduate subject year. Once admitted, pre-service teachers complete six compulsory courses focusing on education and pedagogy (including diversity and inclusion), curriculum design, and professional experience (practical teaching experience in schools). For pre-service teachers to teach digital technology at the secondary level (or CT/DDDO), they must have either a Bachelor of Information Technology, or have completed a 300-level Information Science or Computing course, as well as the required credits from 100- and 200-level courses [56].

At a different university, the University of Canterbury, there is a course for in-service teachers called 'Teaching Computing Programming'. This course equips students (many of whom are primary and secondary teachers, or facilitators of professional development) in understanding what programming is, and the approaches necessary to teach programming. A key aspect to the course is developing, implementing and critically evaluating how they teach programming [52].

In addition, The Mind Lab (a collaboration between an independent education provider and Unitec) offers post-graduate courses to teachers and school leaders primarily focusing on leadership, research, and digital learning across all areas. Recently, after the new digital technology learning area curriculum release, the Mind Lab created an online program for teachers and parents to learn and understand the new CT and DDDO strands (called the digital passport). The digital passport was a mini-course with videos and quizzes covering the progress outcomes, except the outcomes for upper high school (NCEA). The course provides examples of how the progress outcomes may be taught in class, but is primarily focused on upskilling educators and parents with the new progress outcomes, unfamiliar vocabulary and digitally-related concepts [21].

4.4.4 *Diversity, Equity, and Inclusion (DEI).*

The New Zealand Curriculum (NZC) has a set of eight principles which embody beliefs about what is important in a national and local school curriculum.

(1) High expectations
(2) Treaty of Waitangi
(3) Cultural diversity
(4) Inclusion
(5) Learning to learn
(6) Community engagement
(7) Coherence

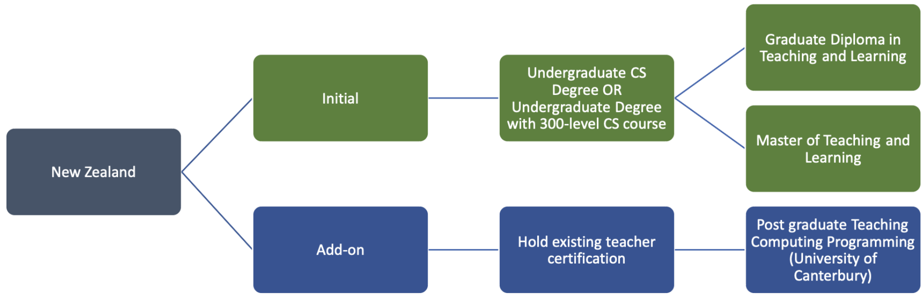

Figure 9: Pathways to CS teacher preparation in New Zealand

(8) Future focus

These principles underpin all school decisions. The principle titled Te Tiriti ō Waitangi (the Treaty of Waitangi]) ensures that schools and teachers deliver a curriculum that: acknowledges the Treaty of Waitangi principles, acknowledges the country's bi-cultural foundations, and enables students to acquire knowledge of Te Reo Māori and tikanga Māori (Māori practices and values) [39]. The principle of cultural diversity means that schools and teachers are required to deliver a curriculum that: reflects a linguistically and culturally diverse nation, affirms students' different cultural identities, incorporates students' cultural contexts into teaching and learning programs, is responsive to diversity within ethnic groups, and helps students understand and respect diverse viewpoints, values, customs, and languages[37].

In terms of equity in CS education, the Otago University Master of Teaching and Learning (MTchgLn) degree also has a section of their course designed for students to learn about diversity and inclusion. This includes the development of culturally responsive, effective pedagogy for diverse learners, incorporating Te Reo Māori and Tikanga Māori into classroom teaching and learning (regardless of the subject) and includes utilizing language, contexts and ways of working [56].

4.4.5 *Emerging Computing Topics.*

The Digital Technology learning area has recently been updated for NCEA level one. The standards are currently being piloted in a select number of schools. One key reason for the reform is the acknowledgment that digital technology is influenced by the worldview and experience of the people who create them: creators have a responsibility to model manaakitanga (show respect, generosity and care) for those who use their digital creations [50].

4.4.6 *Challenges.*

Both the New Zealand curriculum, and Te Marautanga o Aotearoa allow flexibility for schools to implement the content how they believe best serves their students and communities. Because of this flexibility, schools have an opportunity and a challenge in providing the resources and support for teachers and students [21]. The main challenges for CS secondary schools/teachers are resourcing (hiring CS qualified teachers), workload (a lot of the content is new to teachers), PD involved, and teacher capability [41] There is also a misconception about the content involved for teaching CS - many school leaders and teachers believe CS is solely about programming and training students to become coders. Although programming is significant in both CT and DDDO at the higher progress outcomes, the scope is wider and involves incorporating computational thinking and utilizing various digital technologies [41].

4.5 Spain

4.5.1 *Background.*

In Spain, in the 2021-22 academic year there has been a total of 8,216,711 students, of which 2,755,980 study Compulsory Secondary Education and Baccalaureate [54]. The Master's Degree in Teacher Training or Master's Degree in Teacher Training for Compulsory Secondary Education and Baccalaureate, Vocational Training and Language Teaching is a university postgraduate degree in education, and is the basic academic requirement in Spain to be an accredited teacher in compulsory secondary education (ESO). This master's degree was established in 2008 in Spain as a result of the application of the Bologna Plan and replaced the Certificate of Pedagogical Aptitude (CAP), although with marked differences due to the new academic structure.

The Master in Teacher Training was created and introduced by Royal Decree 1834/2008 which brought the end of the Certificate of Pedagogical Aptitude (CAP), whose last organization was the academic year 2008-2009. The Master in Teacher Training aims to accredit the pedagogical and didactic training required by Organic Law 2/2006 on Education to teach in the educational system.

As established by the Organic Law of Education (LOE) in its article 94[55], to teach compulsory secondary education and baccalaureate it will be necessary to have a university degree (Bachelor's degree) in addition to pedagogical and didactic training at Postgraduate level. Same as article 100 of the LOE [55], according to which, to teach a different educational levels regulated in the LOE, it will be necessary to be in possession of the corresponding academic qualifications and have the pedagogical and didactic training that the government establishes for each teaching .

Today, the pedagogical and didactic training of teachers is carried out through the Master in Teacher Training, which consists of 60 ECTS Credits and 1 academic year, with teaching practices in schools. This master's degree qualifies for the profession of Teacher of Compulsory Secondary Education and Baccalaureate, Vocational Training and Language Teaching, Order EDU/3498/2011 which modifies ORDER ECI/3858/2007, which establishes the requirements for the verification of the official university qualifications that qualify for the exercise of the professions of Teacher of Compulsory Secondary Education and Baccalaureate, Professional Training and Language Teaching.

The Master in Teacher Training has limited the specialties according to the university degree (in addition to now being a postgraduate degree). Among the specialties of the Master there is Computer Science and Technology specialty, which is the one that best fits for teaching CS at Secondary level.

In Spain CS is taught in secondary education at the moment in the following courses and subjects:

- 12 years old with a Computational Sciences Course (elective in some high schools only)
- 13 and 14 years old with Technology, Programming and Robotics (mandatory in Madrid Province, with other names in other autonomous communities that offer it)
- 15 years old with Technology, Programming and Robotics (elective or mandatory depending on the academic path chosen)
- There used to be two more courses taught to 16 and 17 years old up until this course, but have been removed from the curricula in 2022

4.5.2 *Current Status.*

Almost all universities in Spain offer the Educational Masters Degree to teach Informatics and Technology, and even some of them are online. Some of the Masters offered in Spain are (see 4).

Table 4: overview of some universities in Spain offering the Educational Master Degree to Teach Informatics & Computer Science

University	City	Degree
Universidad Rey Juan Carlos	Madrid	Master's Degree in Teacher Training in Secondary Education, Baccalaureate, Vocational Training and Languages
Universitat de Valencia	Valencia	Master´s degree in Secondary Education Teacher Training
Universidad de Alicante	Alicante	University Master's degree in Academic Staff of Secondary Education and High School, Vocational Training and Language Teaching
Universidad Autónoma de Barcelona	Barcelona	Official master´s degree in Teaching in Secondary Schools, Vocational Training and Language Centres

4.5.3 *Teacher preparation requirements and policy.*

CS Teachers in Spain are required to study for a master's in education preferable with the specialty of Informatics and Technology (Master's Degree in Secondary Education Teachers: Computer Science and Technology specialty) of one year, 60 ECTS credits (approx. 600 hours). This master degree program generally include 2 months of in-site training program for the students. To be able to apply for this master they have to have an undergraduate degree in CS (desirable), but those with undergraduate degrees in engineering or sciences (math, physics, etc.) can also apply. The standard path is to have an undergraduate degree in CS, mathematics, physics or in certain engineering (industrial, electronic or telecommunications) and master's degree in education with the specialty. It should be noted that what allows access to a teaching certification is the undergraduate degree, not the specialty of the master's degree. Thus, CS teachers in Spain need to have undergraduate degree in CS, engineering, or science that allows them to teach CS in Secondary Education. In the case of in-service secondary school teachers from other disciplines, they can obtain an authorization as long as they meet the requirements of the undergraduate degree. The content of the masters' degree in secondary education with speciality in computer science and technology stipulates that the teacher demonstrate evidence and 60 ECTS in CS and PCSE to include the study of all the following essential areas: 1) Learning and Development of personality; 2) Center Organization and Management; 3) Educational innovation and ICTs applied to the teaching of computer science and technology; 4) Educational research applied to computing and technology; 5) Society, family and education; 6) Psychosocial relationships in the classrooms; 7) Curriculum design in computer science and technology; 7) Complements for disciplinary training I: Technology; 8) Complements for disciplinary training II: Computer Science; 9) Informatics and technology teaching; 10) Practicum; 11) Master´s thesis.

4.5.4 *Diversity, Equity, and Inclusion (DEI).*

Diversity, equity, and inclusion are treated in all the subjects of the master's degree in a transversal way, giving the importance it has from each of the points of view that each subject has.

4.5.5 *Emerging Computing Topics.*

Since the ICT subjects in Baccalaureate have been eliminated in 2022, there are no emerging computing topics, but CS knowledge that was taught in these subjects has been withdrawn.

4.5.6 *Challenges.*

One challenge to introduce any coherent novelty into the Spanish curriculum is the decentralization of educational competencies to the regional governments [59]. In the last educational reform (LOMLOE), the Ministry of Education has removed computer subjects from Baccalaureate (old ICTs). While 42 subjects have been established for all modalities, there is no place for computing. Numerous scientific, professional and educational societies related to Computer Science have prepared a manifesto in support of the implementation of compulsory Computer Science subjects in high school [57]. The entities that promote this manifesto expressed their surprise and rejection of the marginalization of computer science in the LOMLOE. In their opinion, the current permeability of computing in all social and professional fields cannot be limited to a purely instrumental training in the use of computers, mobile devices and software (digital competence), without providing any education in the scientific and technological principles of this discipline. They also rejected some regional initiatives to offer courses

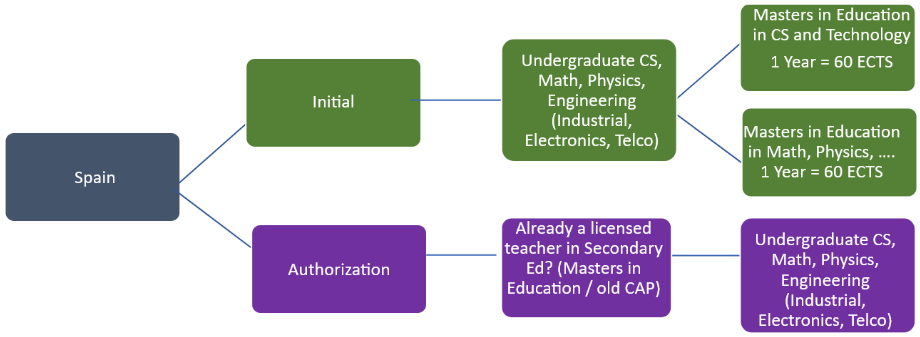

Figure 10: Pathways to CS teacher preparation in Spain

on emerging topics without a previous general education in informatics, e.g. Artificial Intelligence. More information in the news on this topic, and also on the manifest page [57].

4.6 United States, Georgia

4.6.1 Background.
Georgia has about 700,000 secondary students in the state. Communities in Georgia are diverse across a number of dimensions including socioeconomic status, urbanity, race, and access to technology and the Internet. CS education has been part of the Career, Technology, and Agriculture Education (CTAE) pathways for a long time, along with other computing topics like web design, game design, and cybersecurity. In 2018, towards formalizing CS education in the state, Georgia added the requirement for CS teachers to be certified to teach in the field of CS specifically. The Georgia legislature passed a law in 2020 that all middle and high schools must offer at least one CS course by 2025, but there are no requirements for students to take CS courses. Currently about 60% of middle and high schools offer standalone CS education, but only 3% of the students take these courses.

Teachers in Georgia are required to be certified in computer science to teach standalone computer science courses at any grade level. The certification requirements are the same for all grade levels, making certification valid for Pre-Kindergarten through 12th grade (i.e., for all primary and secondary students). There are three pathways to certification: 1) passing a content test, similar to AP CS-A exam, 2) completing an endorsement program that adds CS to a teaching certificate in another discipline, and 3) completing an initial teacher preparation program that gives a teaching certificate in CS.

Because certification requirements include all grade levels, there is only one initial teacher preparation program in CS due to the requirements to be able to teach all students. For example, teachers would need to complete field experiences in elementary, middle, and high school. Most programs, instead, are endorsement programs that add-on CS certification to an existing teaching certification, or teachers take test preparation courses to pass the test. Endorsement programs are offered by universities, Regional Education Service Agencies (RESAs), and some of the larger districts. There are also RESA-provided and for-profit courses that prepare teachers to past the test.

The main difference in the endorsement programs and test preparation pathways is that the test includes only information about content knowledge, not pedagogical knowledge. Typically, teachers who already have some CS content knowledge, or who simply cannot afford an endorsement program, choose this option. Teachers who have no prior knowledge of CS content or who want to learn more about how to teach CS (i.e., PCK) will choose an endorsement program. Both pathways have lower participation in the past two years than the first couple of years after the CS certification requirement started in 2018, which could be a consequence of COVID and the demands on teachers' time. The initial surge in certification during the first couple of years was by teacher who were already teaching CS and just needed to be certified.

4.6.2 Current Status.
The number of endorsement programs has grown rapidly in the past few years from 3 in 2019 (the first year accredited programs could run after the 2018 certification requirement) to around 15 in 2022. The first three programs were all offered by universities, and the remaining programs have been developed in the RESAs. One program is at a large district that needs to certify 15-20 teachers per year. The RESA programs have become more popular because they are cheaper and more local than the university programs. As a result, most newly certified CS teachers are in-service teachers, and there is little teacher development in CS at the universities.

4.6.3 Teacher preparation requirements and policy.

Georgia has teacher standards for CS set by our Professional Standards Commission, which grants teaching certificates. Each standard has several sub-standards to specify skills. We do not have required contact hours or credit hours for the endorsement, but most of the programs have independently designed their programs into include roughly the same 4 courses to cover the following 8 standards:

(1) Computational Thinking - The program shall prepare candidates who demonstrate computational thinking skills to formalize a problem and express its solution in a way that computers (human and machine) can effectively carry out.

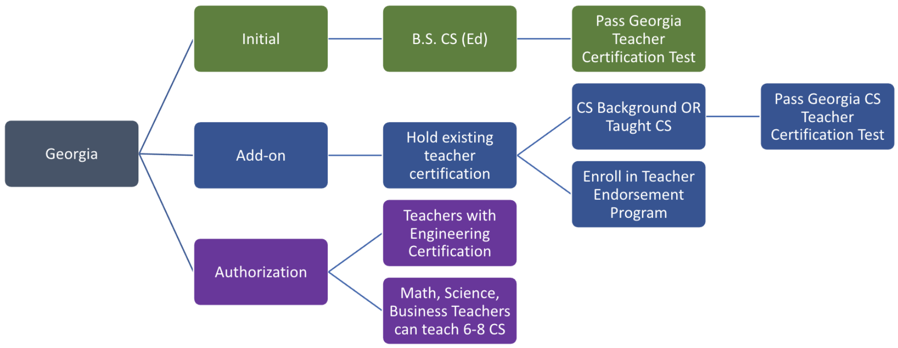

Figure 11: Pathways to CS teacher preparation in Georgia

(2) Programming - The program shall prepare candidates who demonstrate proficiency in at least one third-generation programming language such as Java, Python, C, or C++.
(3) Computer systems - The program shall prepare candidates who demonstrate proficiency in basic computer system components and organization.
(4) Networks & Internet - The program shall prepare candidates who demonstrate proficiency in fundamental principles of computer networks and the Internet.
(5) Digital Literacy and Data - The program shall prepare candidates who demonstrate proficiency in effectively and responsibly using computer applications to create digital artifacts, analyze data, model and simulate phenomena suggested by research and/or data.
(6) Cybersecurity - The program shall prepare candidates who demonstrate proficiency and understanding of security, privacy, and safety concerns in computer systems, networks, and applications.
(7) PCK and TPACK - The program shall prepare candidates who plan, organize, deliver, and evaluate instruction that effectively utilizes current technology for teaching computational thinking principles, computer programming and its applications.
(8) Community Engagement - The program shall prepare candidates who work with business and industry leaders in establishing school/business partnerships and advisory committees and operate student organizations as appropriate.

An important distinction when considering these standards is that they apply only to CS endorsement programs. If teachers pass the test, which measures only programming knowledge in standard 2, they do not have to show competency in any other standards. In contrast, accredited endorsement programs must show how they achieve each of these standards in addition to providing field experiences at the elementary, middle, and high school level. The field experience requirements are much less than for an initial teacher preparation program, though. One program at Georgia State University (GSU) has about 2 weeks of field experiences, whereas the requirement would take 2 years in an initial teacher preparation program.

4.6.4 *Diversity, Equity, and Inclusion (DEI).*

Because they work with primarily in-service teachers, GSU courses leverage their existing experiences and skills in equitable teaching practices and apply it to CS instruction. Many of the teachers already engage in equitable education practices that make sense for their students (e.g., the needs are different in a low-income urban school district than a low-technology rural school district). The GSU courses explicitly ask teachers to apply their existing practices to CS education, and program educates them on CS-specific equity issues. For example, teachers learn how encouragement from a teacher to take a CS class is a strong predictor of whether a student will take CS.

4.6.5 *Emerging Computing Topics.*

The GSU program focuses on foundational computing concepts and computational thinking, and cannot fit more specialized or advanced computational ideas, such as machine learning or AI, as part of credentials for CS teachers. However, it would be useful for teachers to have a curated list of professional development opportunities to engage with specialized or advanced concepts to respond to their students' interests, such as web design or game design. These interests are often regional due to industries in their area. For example, Columbus, GA, has a large cybersecurity industry, and students in that area are often interested in taking advanced courses in cybersecurity beyond the basics taught in CS courses.

4.6.6 *Challenges.*

The primary challenge is recruiting teachers to be CS teachers, and a major barrier is the cost, in both time and money, for becoming certified. The endorsement program at Georgia State University, which is 4 courses, costs $7000 USD based on current tuition rates. The programs at the RESAs cost about half as much. Teachers, however, are not compensated for engaging in this extra development. They also do not receive a pay increase for achieving this extra certification. The state legislature is considering offering a pay increase for CS teachers (i.e., annual pay, not a one-time stipend), but they have not made progress towards this goal in a few years.

The state is also considering reducing certification requirements for elementary and middle school teachers so that they do not have to meet the requirements for high school, lowering the barriers for non-high-school teachers.

A separate challenge for CS teachers in the state, apart from certification requirements, is that many of them are isolated as CS teachers in their schools or districts. Many schools have one CS teacher, and many schools in rural districts might have one CS teachers per district. Thus, they do not get the same support in schools that teachers of other disciplines do. It is harder for them to get quality feedback on their teaching or to benefit from another teacher's experience and ideas.

4.7 United States, Indiana

4.7.1 Background.

Although some Indiana schools have taught CS since the 1980s, computer science increased substantially starting in 2016 when they created and adopted new, required K-12 CS standards. Indiana is one of six states to have adopted all nine policies that are thought to impact CS K-12 education [13]. In 2018, Indiana passed legislation that required that all high schools offer at least one CS course each year by the fall of 2021 [3]. In Indiana, high school refers to secondary schools with students typically aged 14-18. This started a dramatic increase in high school CS offerings across the state [44]. During the 2017-2018 school year, 10,141 students completed a CS course, which has now increased to 19,377 students 2020-2021 school year [53]. Stakeholders have suggested that this increase was due, in part, to this policy that promotes CS education. However, while these numbers have increased, Indiana is still not reaching a broad range of students.

4.7.2 Current Status.

In 2021, there were 341,646 high school students in Indiana [53], which amounts to less than 6% of all high school students taking a CS course during the 2020-2021 school year. In addition, only 21% of those taking a CS course were female (Code et al., 2021). Indiana has 682 high schools. In 2021, 74% of Indiana high schools offered at least one CS course [13]. In 2021, Indiana also reported that there were 416 teachers who taught CS from 303 high schools [44]. However, these licenses varied greatly. Koressel et al. [44] grouped the licenses of teachers teaching high school CS into three categories: CS-Related (e.g., Career and Technical Education, Computer Science, Cybersecurity, etc.), approved (e.g., science, business, math), and not approved (e.g., administration, special education, social studies, english, etc.). Koressel found that 85% of teachers in Indiana public high schools who taught CS had a CS-Related or Approved license.

4.7.3 Teacher preparation requirements and policy.

To teach secondary CS in Indiana, teachers must have an approved license. Although there is technically an option at the Indiana Department of Education for an initial license in Computer Science, few existing programs due to lack of interest. Although four traditional undergraduate teacher education programs have stand alone initial CS license offering, in 2021, none of these programs produced a single graduate. According to Title 2 data (2021 Title II Data), three alternative teacher education programs offer computer science licensure programs. The alternative programs require an undergraduate computer science degree, and pre-service teachers complete an additional pedagogical experience at a higher education institution. However, only two graduates completed these programs in 2021. There is also an add-on undergraduate computer science teacher program, which graduates approximately five K-12 computer science teachers each year. In all of these programs, pre-service teachers must take and pass the state CS teacher certification test. In terms of authorization, if a teacher has an existing license in business or career/technical education, they are authorized to teach high school computer science with no additional requirements. If a teacher has an existing license in math, science, technology education, or information technology, with additional professional development requirements, they can also teach a high school CS course.

The computer science license is typically a supplementary or add-on license and requires that teachers pass the Praxis 5652 test. The CS license is a K-12 license, meaning that teachers with this license can teach CS at all grades from Kindergarten to 12th grade. The Indiana Department of Education recently changed their license title from Computer Education to Computer Science (CS). In 2019, the license changed from a broader license that focused on broader ideas around computing, to one that focused more heavily on computer science. This required programs to shift to focus on specific computer science concepts and courses. The computer education license was previously earned by passing the Pearson 013 test (which integrated many aspects of technology integration, such as network installation and best literacy approaches with technology). The new test being used is the Praxis 5652. This test is focused completely on CS concepts and practices. Within the state of Indiana, there are technically two pre-service programs which are add-on or supplemental licenses: Ball State University and Indiana University Bloomington. Ball State University's pre-service Computer Education licensure program is primarily focused on educational technology, which is in line with the previous license. Indiana University's pre-service Computer Science Licensure program focuses more on preparing pre-service teachers to teach computer science. However, pre-service teachers who want to teach CS are not required to take a pre-service program. Instead, they can simply take the CS test to add a CS license to their initial license in another subject area (e.g., Math, English, etc.).

Indiana University has an add-on or supplemental K-12 CS license for pre-service teachers (active) and inservice teachers (inactive). The teachers need to have (or be currently pursuing) an existing license in another area, either elementary education or secondary education (in a variety of subject areas such as social studies, mathematics, etc). The program is made up of four courses, with an additional six weeks of student teaching and an optional one-credit hour course for test preparation (see Table below for overview of four courses).

The W200 educational technology course required for all pre-service teachers (K-12). Out of the 16 weeks, four weeks cover CT/CS concepts: (1) Introduction to computing, binary, and computer basics; (2) Internet, big data, AI; (3) CT and educational robots; and (4) Block-based coding. In each class session, instructors model a K-12 CT/CS lesson and discuss pedagogical strategies used, as well as how pre-service teachers would incorporate CT into their own

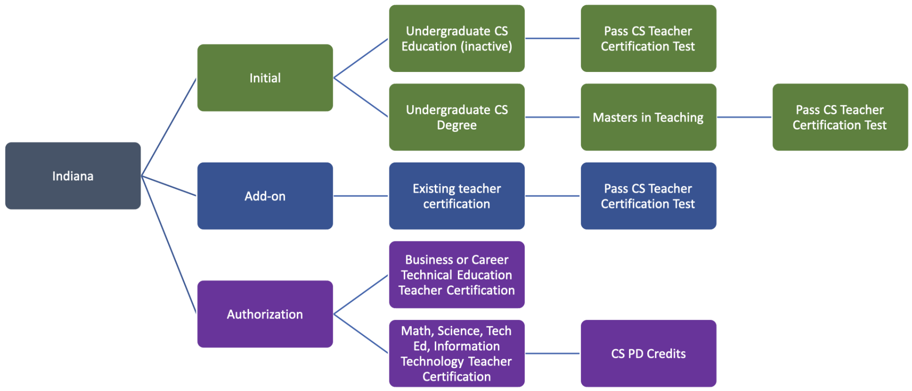

Figure 12: Pathways to CS teacher preparation in Indiana

Table 5: Overview of Courses in Pre-Service Computer Science Teacher Education Program at Indiana University

W200 Using Computers in Education (3 credit hours)
W210 Introduction to K-12 Computing, Computer Science, and Technology Integration (3 credit hours)
W220 Computer Science and Programming in K-12 Classrooms (3 credit hours)
W310 K-12 Computing and Computer Science Teaching Methods (3 credit hours)
W410: CS Student Teaching Practicum (6 credit hours)
W401 (optional) Preparation for the Computer Science Praxis Test (1 credit hour)

future classrooms. These activities included unplugged, plugged, and simulation/field experience activities. The next course in the program is W210, which provides an introduction to block-based programming, HTML, and a short field experience. This introduction allows pre-service teachers with little CS experience to immerse themselves in basic CS ideas utilizing unplugged and computational toys such as robotics. The next course in the sequence is W220, which covers CS concepts in depth. In addition, pre-service teachers learn how to program in Python and complete a final project in Python. W310 is the CS methods course wherein students are guided through an example curriculum that aligns with a popular introductory CS course: AP CS Principles. pre-service teachers are expected to complete at least 20 hours of field experience. They are observed formally at least once in their field experiences. Each week, they are expected to provide some description, analysis, and reflection of their ongoing field experiences as they relate to the CS standards. Students are evaluated based on their efforts, attitudes, as well as their abilities to thoughtfully reflect and show continuous growth throughout the semester. The final course is their student teaching practicum, W410, Practicum in Computer Science Education (6 cr). Since it is an add-on licensure program, Indiana University requires that students in our secondary computer educator program perform 6 weeks of teaching CS related courses (e.g., computer applications, computer science). Students are observed twice during this period by a university supervisor and receive detailed feedback on their instructional materials and practices.

4.7.4 *Diversity, Equity, and Inclusion (DEI).*

Within two courses (W200 and W310), there are specific activities around addressing diversity, equity, and inclusion within computer science. One of these activities within the methods course (W310) utilizes MIT's Teacher Moments case study simulations (https://teachermoments.mit.edu/). Using the Teacher Moments case studies, pre-service teachers consider how to address issues associated with diversity, equity, and inclusion in their fake CS classrooms. In addition, all pre-service programs at Indiana University have a required teaching in a pluralistic society class, which addresses issues of social justice, racial inequities, and addressing diverse students' needs.

4.7.5 *Emerging Computing Topics.*

Our program focuses primarily on foundational computer science ideas. pre-service teachers are prepared to teach the secondary introductory CS course (AP CS Principles). However, in the introductory educational technology course, one week is focused on artificial intelligence and data science. pre-service teachers are introduced to various AI and machine learning activities such as Google's Teachable Machine (https://teachablemachine.withgoogle.com/) and Machine Learning for Kids (https://machinelearningforkids.co.uk/). All pre-service teachers also design and develop their own ePortfolios wherein they learn about HTML and website design. Throughout all the courses, pre-service teachers are also introduce to a wide range of various computational toys such as robotics and manipulatives and sensors. However, these topics are highlighted as pedagogical teaching tools as opposed to focused in-depth on the emerging computing content.

4.7.6 Challenges.

There are currently many pathways for teachers to be able to teach CS. While this has expanded access, this has also created some confusion and concern around rigor. At Indiana University, there is a constant balancing act for designing the pre-service undergraduate CS teacher education program due to the various constraints. For example, we have to be cautious on the number of courses required. Although pre-service teachers need more CS content knowledge, adding on additional courses would decrease the number of pre-service teachers that would pursue the CS license addition. At Indiana University, in order to offer courses, our administration has asked that we recruit more pre-service teachers (typically 18 is the required minimum number of students to offer an undergraduate course). However, the computer science teacher education program has rarely had this many pre-service teachers enrolled in the program. The class sizes are typically 3-10 students. Therefore, in efforts to increase enrollment, we condensed the courses to four additional courses, and provided options to take the courses online or face-to-face. In addition, since most pre-service teachers have little to no experience with CS,, the courses need a gradual build in terms of rigor. Although we have attempted to achieve this through the introductory W210 course with block-based coding, we have seen pre-service teachers become overwhelmed by W220 (the programming heavy course) and decide to drop out of the program. There is a constant tension to incorporate enough CS content to enable pre-service teachers to feel comfortable to teach CS, while also ensuring that enough pre-service teachers enroll in the program to continue to offer it. Our pre-service teachers also have limited pedagogical knowledge. The CS teacher education courses are typically taken earlier in their teacher education program as W200 often serves as a recruitment course and is one of the first courses they take at Indiana University. Therefore, much of the CS content is taught by modeling how to teach K-12 students. This tends to decrease anxiety around learning new content and new pedagogical approaches. Another struggle with our program is because the Indiana CS license is K-12, approximately half of the pre-service teachers are enrolled in CS with the intention to teach CS at the primary level. Therefore, activities and model lesson plans need to incorporate adaptations for young children to young adults. Finally, as Indiana University is the only pre-service program offered within the state, it can also be limiting who can add-on CS at the pre-service level. Indiana University is one of the top institutions in the state, with restrictive entry requirements and higher tuition costs (comparatively with the rest of the state).

4.8 United States, Michigan

4.8.1 Background.

Michigan does not currently have a state plan for K-12 computer science, however, the state adopted the K-12 Computer Science Standards in 2019. The standards provide guidance for what students need to know about various CS elements, yet the state does not have a plan on how to accomplish the goals, and timelines for achieving the goals, it appears difficult to support CS as a fundamental part of Michigan's education system. Two hundred and thirty seven schools offered AP computer science in 2019 and 2020; however, Michigan did not graduate a single new CS teacher in 2018 (Code.org, 2018).

Table 6: Code.org CS course offerings in Michigan by locale

Grade Level	Rural	Town	Suburb	City
No CS	688	334	905	638
Elementary CS	249	133	406	168
Middle School CS	126	64	139	62
High School CS	93	44	97	43

4.8.2 Current Status.

After July 1, 2026, the State of Michigan Department of Education (MDE) no longer requires the endorsement required to teach Computer Science. In addition, MDE also decided that endorsements would not be required for teaching these subject areas beginning with 2017 summer programs and starting the 2017-2018 school year. The letter from the MDE stated that while teachers with the CS endorsements were still considered to be appropriately placed in CS classrooms, administrators could use discretion when assigning teachers to CS courses. So, a teacher with a computer science endorsement may still be assigned to teach computer science. Or, an administrator may place a teacher in the assignment who is certified at the grade level and has demonstrated strong computer science skills, but does not hold a computer science endorsement [40]. The push to remove certification requirements is primarily driven by the need to expand access to computer science to primary and secondary learners as educating CS teachers through teacher preparation is seen as a barrier. As a result of the push to increase access, schools can assign any teacher to teach CS, who generally learn about teaching CS by attending a 1-2 week workshop. Although there is a push for teachers to complete CS workshops, Michigan does not dedicate funding for professional development and course support. One of the main CS curriculum being implemented in Michigan is through Code.org. Table 6 indicates the numbers of schools offering CS courses at the elementary, middle, and high school level.

4.8.3 Teacher preparation requirements and policy.

While CS teachers with existing licensure before 2017 can still be assigned to teach CS, there are currently no certification teachers to be licensed to teach CS given that Michigan phased out CS endorsement during 2017. After MDE phased out the endorsement, teacher preparation programs also phased out their pre-service programs in CS education. Since decisions on who can teach CS are made at the local district level by the school administration, teachers with certification in any subject area can teach CS mainly after a 1-2 week professional development. While pre-service programs are currently not being offered in the state, Michigan State University (MSU) offers a graduate certificate in K-12 Computer Science Education for in-service teachers who want to teach CS as a standalone subject or integrate CS into their specific disciplinary context. The graduate certificate provides teachers with a broad overview of CS, programming, and creative computing concepts.

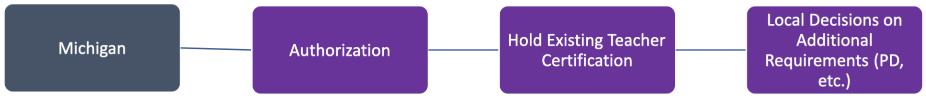

Figure 13: Pathways to CS teacher preparation in Michigan

4.8.4 Diversity, Equity, and Inclusion (DEI).

Given that currently there are no CS teacher preparation programs in Michigan, it is unclear how teachers are prepared to focus on diversity, equity, and inclusion beyond what they may learn in an initial licensure program. The MSU program states that the coursework teachers learn computer science concepts and skills through culturally relevant pedagogy, attending to how culture and context impact student learning.

4.8.5 Emerging Computing Topics.

It is unclear how teachers learn about emerging computing areas outside of any professional development they might receive.

4.8.6 Challenges.

As a result of MDE removing licensure requirements for teaching CS, most universities and colleges stopped offering their CS programs. While Michigan has a number of well-qualified CS teachers who obtained their endorsement prior to 2017, the current model means that few teachers are well-qualified to teach CS at the secondary level. The focus on educating teachers through short-term professional development doesn't offer them the depth needed to offer high quality CS instruction.

4.9 United States, Ohio

4.9.1 Background.

There are approximately 1.8 million students, with 1,360 high schools in Ohio, made up of 1,152 public schools and 208 private schools. The total number of students in grades 9-12 (high/secondary school) is 475,436. Computer science is not mandatory for graduation, therefore leaving the CS course options up to individual schools and districts. Ohio's teacher preparation efforts have been concentrated in Northeast Ohio, where the vast majority of teacher professional development occurs. In the Cleveland Metropolitan School District, Computer Science for Cleveland (CSforCLE) has been leading the CS teacher preparation efforts in Ohio since 2013. The mission of the project is to create equity and opportunity where all scholars engage and explore computer science, and this begins with rigorous, focused teacher preparation. The work of CSforCLE has resulted in 50% of high-schools offering computer science courses, with 754 students currently enrolled.

4.9.2 Current Status.

In 2017, Ohio passed a bill (HB170) to create standards for CS; then enacted bill (HB 166) in 2019 that gave teachers 2 year teaching provision and reauthorized the bill (HB 110) again in 2021 to give teachers more time to go through the endorsement process. As a result, each school district can decide how/when to grant unlicensed CS teachers the opportunity to teach CS. This process is not streamlined and varies across districts. For example, The Cleveland Metropolitan School District recently endorsed the requirement of an evidenced based PD (chosen at the discretion of school/teacher/principal) with eventual progress towards requiring CS teaching endorsement for incoming teachers to teach CS starting Fall 2022.

4.9.3 Teacher preparation requirements and policy .

Currently, in-service teachers can teach CS at all grade levels with the approval of the principal or district level official. There are no state requirements that a teacher must have a current computer science endorsement to teach CS. However, depending on the way the class is coded into the course management system, there may be requirements. For example, if CS is coded as a math class, then only a licensed math teacher can teach the class. This rule subsequently applies to all subject areas outside of CS, and further complicates the process.

Currently, Ohio has 4 inactive computer science education programs for pre-service teachers and have graduated no CS teachers recently. At the in-service level, HB 110 in 2021 granted an extension of the initial 2-year policy that gave in-service teachers grace period to teach CS without an endorsement. While the majority of schools in the state don't require an endorsement, some districts are moving towards certification requirements for CS teachers while providing a time cushion for teachers to seek the endorsement. Teachers can obtain the supplemental endorsement through a two-year multi-step process that involves the following components:

(1) Passing the Ohio Assessment of Educators test for CS, a Pearson created exam specific to Ohio
(2) 2 years of teaching
(3) 2 years of mentorship from a licensed computer science teacher
(4) Evidence of successful passage of a CS methods course.

The Ohio Department of Education also issues 12-hour and 40-hour temporary teaching permits to non-licensed individuals who have at least a bachelor's degree from an accredited university or significant work experience in the subject area to be taught and have been hired to teach in an Ohio school. This allows schools to hire individuals without any teaching license to teach CS on an emergency basis.

4.9.4 Diversity, Equity, and Inclusion (DEI).

The CSforCLE project provides teachers with culturally responsive teaching (CRT) professional development, which includes topics centered around working with marginalized groups, race and CS, inclusion, equity, access, power structures, social and educational justice, and being culturally sensitive to all students. In addition, on-going professional learning communities offer continued CRT support, with activities and sessions that dive further into creating

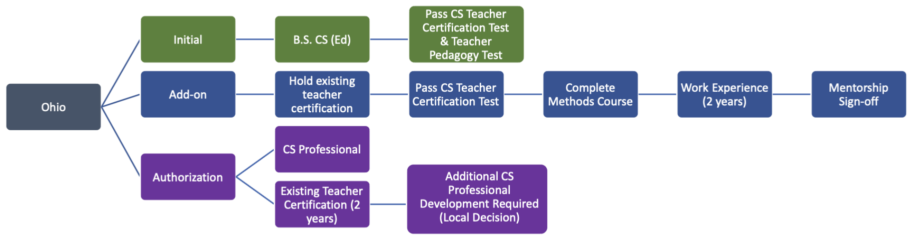

Figure 14: Pathways to CS teacher preparation in Ohio

accessible and equitable CS experiences for all students, especially those that are underserved, minoritized, and disadvantaged by the educational system.

4.9.5 Emerging Computing Topics.
The Ohio Learning Standards and Model Curriculum for Computer Science, which serves as a direct link to teacher preparation content knowledge needs, were recently updated and revised to reflect current trends in CS education and provide a guide for CS educators. The Internet of Things (IoT) and Quantum Computing were new additions, while Computing Systems, Networks and the Internet, Data and Analysis, Cybersecurity, Artificial Intelligence, Algorithms and Programming, Impacts of Computing and Career Connections were reviewed and updated as needed. The Model Curriculum that accompanies the standards were also updated. These changes drive the content knowledge needs of teachers as well as teacher preparation programs.

4.9.6 Challenges.
Ohio faces several challenges for preparing CS teacher listed below

- In-service teachers are typically pulled from other subjects, reducing the sustainability of CS programs as they often are switched back into their primary area of specialty.
- Lack of active CS pre-service Education programs in Ohio and limited programs on a national level.
- Teacher preparation programs are expensive and time consuming.
- Teaches in resource poor districts don't have the financial support to attend training workshops and receive adequate CS knowledge and skills.

4.10 United States, Texas

4.10.1 Background.
Texas has approximately 1.5 million high school students (defined as students in grades 9-12) spread across over 2,000 public high schools (defined as regular instructional campuses that serve at least one grade 9-12). Approximately half of all high schools in the state offer one or more CS courses despite the fact that all high schools have been required since 2013 to offer at least one CS course. However, due to the fact that larger high schools are more likely to offer CS than smaller schools in Texas, approximately 70% of all high school students attend a school that offers one or more CS courses. Of those students, only about 4% enrolled in a CS courses in the 2020-21 school year.

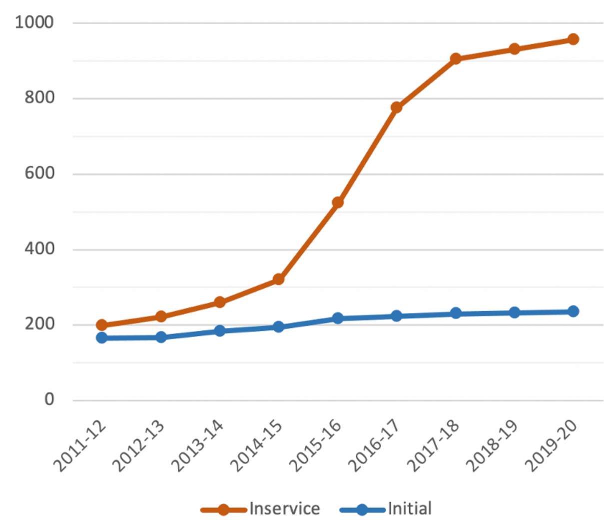

Figure 15: Number of certified CS teachers in TX by CS certification type

Texas has one educator certification that is specific to CS, "Computer Science - Grades 8-12." This certification is required to teach Computer Science I, II, and III in the state. It also qualifies teachers to teach other CS courses, such as Fundamentals of Computer Science, Advanced Placement Computer Science A, Advanced Placement Computer Science Principles, Discrete Mathematics for Computer Science, among others, but it is not technically necessary as there are other technology-related certifications that would also allow teachers to teach these courses.

4.10.2 Current Status.
As of the 2019-20 school year, Texas had approximately 1,300 teachers that were certified in CS. Of these, over 80% obtained their CS certification after having already been certified in another subject area (see Figure 15).

4.10.3 Teacher preparation requirements and policy.
There are three main requirements for obtaining teacher licensure in Texas: obtain a baccalaureate degree, complete an approved educator preparation program, and pass the appropriate certification exam. Teachers need to complete the first two requirements only once.

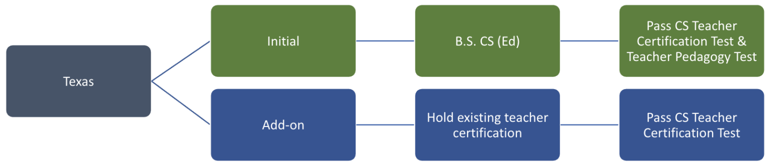

Figure 16: Pathways to CS teacher preparation in Texas

There are two main types of educator preparation programs. One is the traditional preparation program that teacher candidates complete in conjunction with their baccalaureate degree. These programs are provided by universities. Through this type of program, teachers complete pedagogy- and content-focused educator preparation courses followed by a six-month practicum in which they teach alongside an experienced teacher full time. Another type of educator preparation program is known as alternative certification programs. These programs are offered by approved non-profit and for-profit organizations and are available to individuals who already hold a baccalaureate degree. These programs involve a mandatory pedagogy-focused course that is usually completed over the course of a few weeks. Any content-specific training that may be needed to pass the certification is the responsibility of the teacher candidate. Once teacher candidates pass the requisite subject area certification exam, they can obtain employment as a full-time teacher, but their certification is placed in a probationary status for at least one full year of teaching. After completion of their first year and with the approval of the principal of the school where they taught, their probationary teaching certificate is converted to a standard certificate. After the initial licensure, teachers can obtain certification in other subject areas or grade levels simply by passing the requisite certification exam (the same exam that is required of those pursuing a given subject area as their initial certification). The exam for CS certification covers the following domains/topics:

- Technology Applications Core, 12.5% (hardware and software; applications; instructional issues)
- Program Design and Development, 35% (software design; software development;, programming languages)
- Programming Language Topics, 40% (data, data structures, and functions; programming processes and OOP; algorithms)
- Specialized Topics, 12.5% (discrete math; digital forensics; robotics; game and mobile app design)

Of the approximately 20% of teachers who obtained certification in CS as their initial licensure, most participated in alternative certification programs. The low numbers of CS teachers who began their teaching career with a CS certification coincides with a dearth of CS-specific pre-service preparation programs in the state.

The dramatic rise in the number of inservice teachers becoming certified in CS beginning in the 2015-16 school year is largely due to the WeTeach_CS program, a collective impact model developed at the University of Texas at Austin (UT Austin) designed to recruit and prepare educators to teach CS. Using interrupted time series analysis, a 2019 study [69] determined that the WeTeach_CS program significantly increased the overall number of CS-certified teachers in the state and the rate at which new CS teachers were getting certified. In the three years prior to the launch of WeTeach_CS in 2015-16, an average of 62 new CS teachers were certified each year, compared to 211 teachers a year in the subsequent three years. During that time, at least 77% of all new CS-certified teachers in the state participated in the WeTeach_CS program to some extent.

A major factor of the success of WeTeach_CS in recruiting new CS teachers may be the Certification Incentive Program, which provides a stipend of $1,000 USD to any Texas teacher who successfully obtains certification to teach CS. To prepare potential CS teachers for the certification exam, UT Austin developed Foundations of CS for Teachers, a six-week online course that covers all the content areas of the CS teacher certification exam. The online nature of the course allowed it to be implemented widely across the state. In fact, a followup study to the one mentioned above found that, after the launch of the WeTeach_CS program, the rate of new CS teachers becoming certified was greater in rural areas than urban and suburban areas [68].

The WeTeach_CS program was most effective in increasing the number of certified CS teachers during the first few years of its inception when Texas leveraged federal funding to support cohorts of teachers across the state through free professional development. During this time, teachers also received stipends for completing the professional development, independent of whether they achieved CS certification. This investment of $11.2 million USD over about two and a half years created the incentives and external support necessary to scale up the number of CS teachers quickly.

4.10.4 Diversity, Equity, and Inclusion (DEI).
WeTeach_CS offers an online course, Strategies for Effective and Inclusive CS Teaching, that is designed to support teachers in creating inclusive CS courses and programs where all students, especially those from minoritized communities, feel a sense of belonging in computing and computing education. The course covers inclusive strategies for recruiting students to enroll in CS courses, methods for working with counselors and other teachers who have the potential to influence students course-taking decisions, understanding one's own unconscious biases, culturally-responsive teaching practices, implications of intersectionality for student identity in CS contexts, using CS as a means for addressing social justice issues, and other topics. The course is led by a trained facilitator and includes synchronous and asynchronous components and is typically completed over seven weeks. This course is not a required component CS teacher licensure in the state, but it can be included

as part of any preparation program for in-service or pre-service teachers.

4.10.5 Emerging Computing Topics.

The WeTeach_CS program offers professional development designed to prepare teachers to teach the newly-added high school cybersecurity courses in the state. Aside from other potential professional development opportunities, and similar to the state of Michigan, it is unclear how teachers in Texas might learn about other emerging computing topics.

4.10.6 Challenges.

One challenge Texas is facing is that the rate of new CS teachers has begun to level off in recent years. This may be due to the fact that the state funding that supported the WeTeach_CS program during its first three years ceased beginning in the 2018-19 school year. This funding provided the means to operate regional "collaboratives" across the state. These collaboratives were led by a small number of instructional specialists who had expertise in different areas important for preparing new CS teachers, such as CS content, pedagogy, and teacher professional development. UT Austin provided each collaborative with funding and resources to recruit and train new CS teachers. Although UT Austin is still offering WeTeach_CS courses and workshops, it is doing so without the aid of established regional collaboratives. Thus, the resources for training new CS teachers are still available, but the systematic organization of boots on the ground that had previously been the means of distributing those resources and bringing new potential CS teachers to the table has been substantially reduced. Another challenge is that the state policy requiring all high schools to offer CS is not enforced. If it were, the number of teachers with CS certifications might be nearly twice the current number as most high schools employ only one CS-certified teacher.

5 RESULTS

5.1 CS Content Knowledge

Each working group member indicated which categories in the K12CS Framework are represented in their secondary CS teacher development programs. The overview of coverage can be viewed in Table 7. Our findings show that The Netherlands and New Zealand have significant coverage of the CS content knowledge that maps on to the K12CS framework whereas Michigan and Ohio have no coverage of the CS content knowledge for teachers because they do not have teacher certification programs. Amongst the participants, Bavaria, Georgia (U.S.), and Indiana (U.S.) also provide substantial coverage of the CS content knowledge that is required while Ireland has several of the knowledge areas optional. It is interesting to note that only New Zealand and Indiana (U.S.) require teachers to have a knowledge about impacts of computing that include an understanding of how technologies can lead to inequities, impact of computing on social interactions, and know law and ethical issues related to computing.

5.1.1 CS content knowledge and Teacher Certification. It is important to note that the the requirement for how CS content knowledge is developed ranges widely across our participating countries/states for someone to become a certified CS teachers. For example, in the Netherlands the requirements included 120 ECTS (European Credits Transfer System) in computer science concepts (discrete mathematics, programming and algorithms, information systems, hardware and networks, fundamentals of CS) and then getting a Masters degree in Education. On the other hand, in Texas someone could develop CS content knowledge on their own and pass the Praxis CS certification exam to become a CS teacher as long as they have a certification in another subject area. Taking the Praxis exam to obtain teacher certification was a requirement in four of the five U.S. states included in this report, except Michigan.

5.2 CS Pedagogical Content Knowledge

To complement CS content knowledge, we also examined what CS pedagogical content knowledge (PCK) that different programs address. Each working group member indicated which categories in Hubwieser et al.'s [34] CS PCK framework are represented in their secondary CS teacher development programs. The overview of coverage can be viewed in Table 8. As reflected in the table, most the programs are similar in that they have even coverage of nearly all categories. The category that regularly was missing was science, suggesting that most programs do not necessarily teach the teaching of CS in an evidence-based, scientific perspective. Again, Michigan and Ohio with no CS teacher preparation programs do not address CS PCK for teachers.

5.3 Pathways to Teaching Standalone CS in Secondary Schools

Across all countries, there were multiple pathways to becoming a secondary CS teacher for those without an existing teaching certificate as well as those with an existing non-CS teaching certificate. However, the requirements for how to become a CS teachers differed significantly across the countries/states we examined. For example, Netherlands had one main pathway (undergraduate degree in CS with an add-on masters in CS education) where as Michigan only requires an existing licensure in any subject area. Detailed information on each country's/state's pathways can be found in each of the case studies.

5.4 CS-specific DEI

We also wanted to examine whether and how CS teacher preparation programs addressed issues of diversity, equity, and inclusion (DEI) given the role computer science plays in the design of technologies that disproportionately harm marginalized individuals and communities [72] as well as the need to ensure all students have access to equitable CS [11]. Our analysis showed that DEI issues varied depending on countries. While most countries addressed elements of diversity or differentiation in their general teacher education program, there were fewer examples of addressing how DEI was specifically addressed in computer science. Furthermore, there were differences in how countries/states described DEI. For example, at Cleveland State University, DEI focused more heavily on engaging marginalized populations based on race and gender, whereas Spain focused more heavily on addressing students with special needs or disabilities. Although several of the programs described in our country/state case studies specifically incorporate DEI in CS issues, this was not a requirement of the country/state.

Table 7: CS Content Knowledge for Secondary Schools, based on K12CS Framework, in Teacher Preparation Programs by Country and State. X = Required, O = Optional, - = Missing

Concept	Bavaria	Ireland	Netherlands	New Zealand	Spain	U.S. GA	U.S. IN	U.S. MI	U.S. OH	U.S. TX
Devices	O	O	X	X	O	X	X	-	-	X
Hard- & Software	X	X	X	X	X	X	X	-	-	X
Troubleshooting	X	-	X	X	X	-	X	-	-	X
Algorithm	X	X	X	X	X	X	X	-	-	X
Variables	X	X	X	X	X	X	X	-	-	X
Control	X	-	X	X	X	X	-	-	-	X
Modularity	X	X	X	-	X	X	X	-	-	X
Program Dev	X	X	X	X	-	-	X	-	-	X
Networks	X	O	O	X	-	X	X	-	-	X
Cybersecurity	O	O	O	X	-	X	-	-	-	X
Data Collect	X	O	X	X	-	X	X	-	-	-
Storage	X	O	X	X	-	X	X	-	-	X
Vis & Transform	X	O	X	X	-	X	-	-	-	X
Inference & Model	X	O	-	-	-	-	-	-	-	-
Culture	-	-	O	X	X	-	X	-	-	-
Social Impact	-	-	O	X	-	-	X	-	-	-
Law & Ethics	-	-	O	X	-	X	X	-	-	X

Table 8: CS PCK for Secondary Schools, based on Hubwieser et al. [34], in Teacher Preparation Programs by Country and State. X = Required, - = Missing

Concept	Bavaria	Ireland	Netherlands	New Zealand	Spain	U.S. GA	U.S. IN	U.S. MI	U.S. OH
Learning content	X	X	X	X	X	X	X	-	-
Subject	X	X	X	X	X	X	X	-	-
Curr & Standard	X	X	X	X	X	X	X	-	-
Objectives	X	X	X	X	X	X	X	-	-
Extra. Activities	X	-	X	X	X	-	X	-	-
Science	X	-	X	-	-	-	-	-	-
Teaching Methods	X	X	X	X	X	X	X	-	-
Subject-specific	X	X	X	X	X	X	X	-	-
Subject Elements	X	X	X	X	X	X	X	-	-
Media	X	X	X	X	X	X	X	-	-
Cognition	X	X	X	X	X	-	X	-	-
Perspectives	X	X	X	X	X	X	X	-	-
School Dev	X	X	-	-	X	-	X	-	-
Ed system	X	X	X	-	X	X	X	-	-

Table 9: Pathways for Someone to Become a CS Teacher in Secondary Schools. X = Pathway to teach CS, - = Not required to teach CS

Requirements without an Existing Teaching Certificate										
Pathway	Bavaria	Ireland	Netherlands	New Zealand	Spain	U.S. GA	U.S. IN	U.S. MI	U.S. OH	
Pre-service Degree in CS Education	X	X	-	-	-	X	-	-	X	X
Undergrad Degree + Teaching Certification	-	X	X	X	X	X	X	-	-	X
Non-Licensed Teacher Waiver	X	-	-	-	-	-	-	-	X	-
Pathway with an Existing Non-CS Teaching Certification										
Pathway	Bavaria	Ireland	Netherlands	New Zealand	Spain	U.S. GA	U.S. IN	U.S. MI	U.S. OH	
Add-on or Masters in CS Education	X	X	X	X	X	X	X	-	-	-
Emergency or Mentorship	-	-	-	X	-	-	-	-	X	-
Test	-	-	-	-	-	X	X	-	X	X
Certification in Another Discipline	-	-	-	X	-	-	X	X	-	-
CS-specific DEI	-	-	-	-	-	-	-	-	-	-

6 DISCUSSION

One of the themes that emerged in our discussions about CS teacher preparation was the challenge of recruiting teacher candidates who wanted to pursue certification within CS education; however, the reasons were different between Europe/NZ and the United States. In Europe and NZ, the undergraduate coursework requirement for becoming certified to teach CS are equivalent to a CS major. As a result, it is difficult to convince students to become CS teachers where pursuing CS degree leads to better paying employment opportunities. On the other hand, the CS teaching certification requirements are add-on/supplemental, which means that pre-service teachers have to take on additional coursework on top of their primary certification area that leads to extra time and tuition costs. As a result, few pre-service teachers pursue CS teaching certification. In addition, U.S. teacher preparation programs offer one CS teacher certification program that spans elementary to secondary education, which make it difficult to differentiate between what elementary teachers need to know about teaching CS and what secondary teachers need to be able to offer high quality CS instruction. Additionally, across the United States and Europe/New Zealand the overall declining enrollment in teacher preparation programs also leads to difficulty in recruiting candidates for CS teacher education programs.

While there has been a considerable increase in CS exposure in primary and secondary schools in the countries/states represented in this study, working group participants reported that pre-service teachers may not have had CS learning experiences in their own schooling; thus, they may carry misconceptions about what CS is and often equate computer literacy with computer science. Consequently and as a result these misconceptions also create hurdles to recruiting pre-service teachers in pursuing CS teaching certification as they may hold stereotypical beliefs that they could not be successful at teaching CS and lack confidence in their ability to do so.

Another issue that emerged from our working group and case studies was related to alternate in-service teacher pathways for certification. As highlighted in some of the case studies, in-service teachers could pursue alternate certification pathways in Spain, Ireland, and U.S. to teach CS; however, working group members raised concerns that these pathways do not provide teachers with adequate knowledge to offer high quality CS instruction. Resulting from a lack of CS knowledge, teachers may feel less agency and confidence to change the curriculum in ways that makes to incorporate culturally responsive computing (CRC). CRC draws on the principles of culturally responsive teaching where students' identities, backgrounds, families, communities are seen as assets on which lessons and classroom instruction is founded [26] [64] [45]. In order to bring CRC into CS instruction, teachers need to foster connections between their classrooms and communities they teach in as well as have in-depth CS knowledge that allows them to adapt the given curriculum to their classroom context. If teachers only expected to learn CS in a week or pass the test to become eligible to teach CS, as is the case in some of our case studies, then the teachers will not have the competencies to offer high quality CS that center their students' lived experiences in the classroom. Given these issues, our working group has some recommendations to ensure that new CS teachers have adequate CS knowledge and supports to provide rigorous CS instruction to their students.

6.1 Recommendation

Building on the discussions included in the design thinking process as well as the case studies, the participants developed several recommendations for improving CS teacher programs around the globe.

One of the main recommendations from our working group is the need to move away from educating new CS teachers through short 1-2 week long professional development (PD) experiences. These short PD experiences are insufficient to develop CS content and pedagogical content knowledge that allows teachers to provide high quality CS instruction that is centered around students' lived experiences. We need to provide additional mechanisms to develop CS teacher knowledge and competencies through University coursework. Case studies presented in this paper provide different models on how teacher knowledge could be developed from standalone certification programs that require equivalent courses to an undergraduate CS degree to supplemental certification programs that require basic CS content knowledge to jurisdictions that do not have any certification requirements. We believe that removing certification requirements altogether just to increase access to CS education is not the right approach as it will lead to inferior CS learning experiences, especially for students from marginalized groups. At the same time, it also may not be feasible to require the same coursework required for CS majors given teachers need different knowledge than a software developer. Schools of Education could develop certification pathways that reduce the number of required coursework to become a CS teacher in conjunction with additional support that continues to develop teachers' knowledge and skills to be a effective CS teacher.

Given that CS majors make significantly higher salaries than CS teachers, countries and states should incentivize becoming a CS teacher by using various incentives such as higher salaries, free tuition, and student loan forgiveness [29]. In addition, CS and education faculty should collaborate to develop CS teacher preparation programs as well as embed computing into core teacher education courses to provide all pre-service teachers exposure to computing concepts and tools [29] [73].

The additional supports may include team-teaching or co-teaching with experienced teachers who have a deep CS knowledge. We could also develop teachers competencies by engaging them in learning communities where teachers can share and learn from each other's problems of practice. The Computing at School (CAS) in the UK provides a potential model to blend face-to-face and online professional development and learning communities to develop teachers' knowledge to teach CS [49]. The CAS includes communities of practice that allows primary and secondary teachers to gain access to continuous professional development as well as peer support that helps them develop their knowledge to teach CS. Learning communities would also allow teachers to keep up-to-date with the constantly evolving field of CS education. In order to develop and sustain these communities requires sustained investment from high education institutions and other stakeholders that involve long-term education opportunities, support for enacting the curriculum, and encouraging teacher agency in CS instruction [63].

The working group also recommends that, preparing only pre-service teachers for secondary CS is not enough to broaden participation into CS. We need to address needs for CS/CT needs in earlier grades that paves the way for the development of computational skills as a life-long process and therefore, eliminating the fear of computing. For example, in New Zealand CS teacher preparation programs focus on developing foundational CS/CT content knowledge for primary and middle school teachers. This means that pre-service teachers need to aware of what CS actually is as they progress through their teacher preparation program. With future teachers prepared to integrate CS/CT into their instruction would also lead to an increased awareness of what constitutes CS in primary schools, which could lead to students taking CS as a core subject at the secondary level.

Finally, the working group recommends that we need to teach CS in equitable ways using culturally responsive-sustaining pedagogy and anti-racist practices [11]. Kapor Center's Equitable CS framework and its six core components should become the inform CS teacher preparation programs and curriculum development in order to "create culturally sustaining, equitable, and inclusive K-12 computer science classrooms" [11]. We recommend that it is important to prepare teachers who can center their students' lived experiences and backgrounds into their CS instruction as well as acknowledge the role CS plays in design of technologies that leads disproportional harm on Black and Brown communities [72]. Yadav and Heath provide a model for how educators can bring justice-oriented CS education into their own classroom through a "participatory and community centered approach to CS curricula which facilitates community co-designed CS, centers criticality, and fosters civic education within CS" [72].

6.2 Future Research

goal of this paper was to report on how CS teachers are prepared academically in various countries, including developing their content knowledge and pedagogical content knowledge. Future research should investigate levels of knowledge CS teachers need provide quality instruction and relationship between teacher knowledge and student outcomes. Specifically, research could examine how teacher knowledge and background influences student outcome including learning, self-efficacy, and sense of belonging.

Future research should also investigate whether and how the development of CT knowledge and skills for pre-service teachers in primary teacher education can lead them to bring rigorous CS experiences into their future classrooms. Furthermore, this research could also study how exposure to CT in core teacher education courses for secondary pre-service teachers could lead them to pursue CS teaching certification. Future research should also focus on how to develop teacher competencies in equitable CS instruction and how to support teachers to connect with local community members in order to bring and connect their expertise to students' CS learning experiences.

6.3 Limitations

One of the limitations of this report is that the working group represented only certain European countries, some U.S states, and New Zealand. As a result, our results only focus on CS teacher education programs within those jurisdictions and limits the CS content and pedagogical content knowledge included in this report. In addition, we used the K12 CS framework to categorize CS content knowledge and Hubwieser and colleagues [34] framework to classify pedagogical content knowledge for CS teachers, which limits the knowledge teachers need to teach CS to what is included in these two frameworks.

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