# The Importance of Context: Assessing the Challenges of K-12 Computing Education through the Lens of Biggs 3P Model

Jordan Allison

## ABSTRACT

The evolution and innovation of technology within society has caused many changes and challenges for computing education. However, the root cause of these challenges are often misunderstood, or neglected. Therefore, this paper deals with the question of identifying the contextual factors that create the challenges which exist in K-12 computing education. To do this, the perspectives of 32 English college employees were considered, with the challenges and contextual factors identified being mapped to Biggs 3P Model of classroom learning. Through this process, in addition to a short comparison between English and Finnish education systems and policy, the 3P Model was re-framed to include the fourth P of Policy consisting of 'government priorities', and 'regulatory bodies'. Findings indicate the extent to which contextual factors influence the challenges and effectiveness of computing education, and how many of these factors are interlinked, despite ranging from macro-environment trends and policy to an individual student's knowledge of programming. Together, these findings raise important philosophical questions of what computing education is, and what the goals of computing education should be. The answers to these questions have significant implications for practice, which practitioners and policy makers must consider for the design of any computing program of study, while the amended 3P Model can be used to identify the contextual factors which may influence the effectiveness of such programs. Furthermore, this paper contributes to the limited body of research concerning English college education, and more specifically perspectives regarding computing education in this context.

## CCS CONCEPTS

• Social and professional topics → Computing education; K12 education.

## KEYWORDS

Computing Education, K-12 Computer Science Education, 3P Model, Teaching Challenges, Philosophy and Purpose of Computing Education

## 1 INTRODUCTION

In the ever-changing, fast evolving and increasingly digital world, much of everyday life has become dependent upon computing [18, 44], and as a result, there are an increasing number of jobs which did not exist just a decade ago [32, 43]. This has resulted in employers facing challenges in finding employees with the right skills for ICT/Computing vacancies [1], leading to what has been described as a 'digital skills gap' [11]. With the global outbreak of COVID-19 causing a shift to more home-based working, and online education, the greater need for computing has been intensified, and this trend of an increasingly digital world is likely to continue without any clear endpoint in sight [28, 42]. Therefore, it is becoming increasingly important that all young people leave their formal K-12 education with the appropriate knowledge, skills, and attitudes that allows them to deal with these societal and technological changes [7], and places a focus on the importance of computing education. One of the goals of education can be described as supporting students in engaging in curricula which will support the needs of the future economy, and the skills that will be required [1, 28]. However, there are a number of challenges that plague computing education, not least due to the rapid rate of change which makes identifying future skills needs difficult. Aničić, Divjak, and Arbanas [1] analysed 155 papers concerning ICT education and ICT careers and found that there are a number of challenges that exist, but few papers propose solutions to these challenges. Many instead simply propose new curriculum, neglecting improvements in pedagogical issues. In fact, many papers identify some of the challenges that exist for computing education whether that be due to such a variety in student backgrounds [35, 41], a lack of staff expertise [27, 46], or insufficient resources [5]. However, what appears to often be neglected in literature is the contextual factors that influence these challenges. Or in other words, what causes these challenges to exist in the first place. Therefore, this paper aims to answer the following research question:

*What are the contextual factors that create the challenges that exist in computing education?*

By gaining a greater understanding of the contextual factors that influence and create the challenges that exist for computing education, practitioners and policy makers can seek to address these challenges at the source, as opposed to merely reacting to the challenges facing them.

The paper is structured as follows:

(1) A conceptual model to frame contextual factors within classroom learning.
(2) Interview findings from English college stakeholders to provide further insight into computing education from an English perspective.
(3) Discussion surrounding comparative education systems and the importance of country context.
(4) Assessing the contextual factors that define the challenges of computing education in relation to the model.
(5) Preliminary conclusions with implications for research and practice, and future work.

## 2 CONCEPTUAL UNDERPINNINGS 2.1 Biggs 3P Model

To frame the contextual factors that create the challenges for computing education, it is first important to distinguish a model that addresses different aspects of the teaching and learning environment. For this paper, the underpinning conceptual model to do this will be Biggs [6] 3P Model, that was adapted from Dunkin and Biddle's presage-process-product model to describe student learning as opposed to teaching and classroom interaction. This model explains how different components within education interact with each other, and because of this, are rooted in educational context.

The first set of factors within the model; presage factors, consist of both the student and the teaching context. For the student, this includes their learning-related characteristics such as their prior knowledge, values, expectations, and approaches to learning. These factors influence how a student behaves in a classroom and ultimately throughout their educational journey. The teaching context refers to both the teacher who themselves bring their own teaching philosophies and prior experiences, values and expectations to the teaching and learning environment, but also more widely the course structure, curriculum, methods of teaching and assessment as set by the institution and teaching team. Students and teaching context (i.e. teachers and institutions), have perceptions of one another which influence how they react and deal with situations in a teaching and learning environment. Hence, in terms of computing education challenges, it can be implied that the cause of challenges may be influenced by a students or teachers prior experience and values, or aspects such as curriculum and teaching methods.

Together, both sets of presage factors influence the next stage of the 3P Model; process. This refers to the execution of the curriculum, or how to go about the process of teaching and learning. Finally, is the nature of outcome, or 'product', which refers to what the product of the teaching and learning is [6]. This could be attributed to being grades, or simply a measure of what was learned. Overall, this model of student learning provides the conceptual view that there is an educational system, or more specifically a classroom system that is comprised of a variety of contextual components. Each component plays a role in dictating how a student learns, where any change in student numbers, curriculum, or assessment, can have wider implications on the other components [6].

## 2.2 What is Computing Education?

Although the 3P Model can provide some contextual framework of where different educational challenges may stem from, it still neglects two important questions that need answering; *'What is computing education?'* and *'What are the goals of computing education?'* This can become confusing rather quickly with the increasingly different uses of terminology, where there is generally a lack of shared understanding of what one term means versus another. These questions, and the definitions of terms are important topics for debate beyond the scope of this paper, but a classic approach is the assumption that those aspects seen as valuable in the subject must also be valuable in society and for students to learn [34]. On the contrary, due to technological advancements and the increase in skills gaps for computing and related subjects, can the goal of computing education be defined as to simply fill these gaps? This still does not identify exactly what those gaps are.

Computing as a discipline can be viewed as a combination of knowledge's, skills, and attitudes, which includes aspects such as computational thinking, an ability to use different tools and software, programming, an understanding of the role of technology in society, or using technology to solve business problems. It is inherently complex to pin down exactly what it is, and therefore, what the goals are in educating students of this subject. However, an analysis of literature can help provide some view of what the goals of computing education should be.

A content analysis of papers showed that students should develop both discipline-specific knowledge and skills, and 'soft' skills such as communication, management, problem solving and leadership skills [1]. This again, can be described as rather generic, as one could say that the goals 'depend' on a variety of contextual factors, which ironically again emphasise the importance of context. What is perhaps a more appropriate view, is that taken by Schulte and Budde [34] in their discussion surrounding Bildung, where they emphasise the need for a bigger picture in computing education. Bildung, although sometimes translated as 'education', this translation neglects the distinctive cultural and historical context of the concept [20]. Bildung is more than just education, it often refers to and includes other factors such as developing critical knowledge, the involvement of values, ethics, and responsibility [39]. It denotes the idea of self-fulfilment, individualisation, and the ability to develop one's own capabilities [34], and focuses on the development of the learner as a person [39]. This is therefore beyond what can be described as learning which is where someone becomes equipped with the knowledge and tools to do something but instead, the ability to learn and develop themselves. Traditional education has typically been ill-prepared in this regard [32], while more and more reports are increasingly identifying the importance of the ability to learn.

The Shadbolt Review of Computer Sciences Degree Accreditation and Graduate Employability [36] found that employers are not looking for graduates with knowledge of a specific programming language, but rather the ability to recognise and select the relevant language for a given task. Besides, due to the changing nature of technology, students need to learn the skills and knowledge required of jobs that do not yet exist, and therefore the tools they will be using may also not yet exist. Hence, what is important in the context of computing education can be argued as developing the capacity in students to be able to become life-long learners, with the ability to adapt to any new situation. Therefore, the traditional models of education which was predominantly focused on a teacher's knowledge of content and disseminating this knowledge to students should no longer be seen as a pedagogical accomplishment which it once was [37]. However, students still need to learn something, and it is the current curricula and tools that will merely act as a guide for computing education, while these other traits as emphasised through Bildung are developed. Contextually, the goals of computing education must therefore be understood, as any challenge for computing education can also be described as a challenge that is impeding the achievements of those set goals.

While a discussion on conceptual models and theoretical questions can be asked, they are still generalist. Therefore, primary research was conducted to allow a greater insight and to augment these discussions surrounding computing education through the investigation of the interconnectedness between the contextual factors, challenges, and the goals of computing education in one specific case.

## 3 METHODS

### 3.1 A Focus on English Education

Within the UK, the four nations of England, Wales, Scotland, and Northern Ireland all have their own separate education system. In 2014, England introduced the New National Curriculum for Computing programmes of study influencing most levels of K-12 education. A key change was that ICT and Computing were set as separate subjects at GCSE level (compulsory education for students aged 14-16), with a major report identifying how the image of Computer Science was seen as specialist, and that there was a focus on Computer Science so much, that this was at the expense of ICT [41]. Additionally, this new curriculum was non-prescriptive, with no specified coding languages, software, or hardware to use.

Since 2014, there have also been a number of qualification reforms within England, including the revision of A-Levels (an academic qualification for students aged 16-18) [41], and a reform on apprenticeships and standards which is 16+ study that is combined with practical training in a job. A-Levels have been viewed as the gold-standard academic route, with apprenticeships viewed as the work-based route of education that serve a key aspect of UK government policy on helping to increase the skill levels of the UK workforce [38]. In 2020 there was also the introduction of T-Levels (another type of qualification for those aged 16-18), which has been described as the 'technical route' of education post GCSE study [40], with the aim to enhance productivity and address skills gaps in key sectors. T-Levels, like apprenticeships, combine study with some practical work experience, but the ratio between work and study is split 1:4, as opposed to the 4:1 of apprenticeships.

Overall, the UK Department for Education [14] state they want to align the majority of post-16 education and training to employer led standards by 2030. However, within England there have already been a number of changes to qualifications and a variety of options available for students, which makes education in England interesting to consider based on this context. Besides, it has been identified that having so many options of study can be confusing for schools and young people. Unlike education systems such as that of Finland where achievement of those leaving school is level across the cohort, this is not the same for the achievement of 16-year olds in England, who instead have a variety of backgrounds, experiences and starting points [4].

Colleges within England, not to be confused with the American definition of college, refer to educational institutions that are predominantly, but not exclusively focused on the two years of compulsory education for students between the ages of 16-18. They prepare students for university or employment, and are a very significant part of mainstream education in England [27]. Colleges were identified in the UK's government report 'Make or Break: The UK's Digital Future' as being pivotal in addressing the skills gaps which exist [18], and are characterised as having a very diverse curricula, and serving students from a variety of backgrounds, including 34% of English 16-18 year olds, and 1.4 million adults [27]. Hence, English colleges were chosen as the subject of inquiry.

### 3.2 Data Collection

A qualitative research method was employed where semi-structured interviews were conducted with employees from 13 of the 23 colleges in the South-West region of England. This region was chosen as it has some interesting characteristics. It is the area within England with the highest proportion of unfilled job vacancies due to a lack of skills [45], and it also has a lack of appropriate employers for graduates of computer science [13]. It is also the region where colleges have the highest staff turnover at 19.9% [3], but also the region where the author is based.

Semi-structured interviews would allow the opportunity to gain an insight into any causal inferences and explanations on specified topics, which is perfect for this study given the focus on context. Interviewees were targeted by first identifying publicly available contact email addresses available on the 23 college websites of those who were deemed relevant to the study, in addition to some known contacts. A snowball sampling technique was then used to identify further contacts. In total, 99 individuals were emailed to take part. No response was received from 39 individuals, 20 were unable to accommodate, but 7 of those provided contact details of colleagues who they thought would be appropriate for the study. 40 individuals initially agreed to be interviewed, but due to issues such as staff availability, only 32 individuals were interviewed. The interviewed employees were varied in experience and job type and consisted of computing lecturers (n=14), heads of department (n=10), and senior leaders such as principles or directors (n=8). This range of perspectives would provide a greater insight into the context, goals, and the challenges faced from both a pedagogical and strategic view.

Interviews were conducted virtually with the majority being conducted via Microsoft Teams. These interviews were recorded and transcribed, and then transcripts were added to the software NVivo to aid the analysis process. The data was coded using guidelines from Braun and Clarke [8], where thematic analysis was used to identify patterns of meaning between data. This involved familiarisation with the data, generating initial codes through complete coding, searching for themes, reviewing themes, and defining and naming themes. Significantly, as with any qualitative research, the themes created are subjective since they are based on the authors interpretation. Hence, interview quotes will be provided as illustrative examples of how the interview data formed the basis of the themes created and arguments made.

## 4 FINDINGS

There were a variety of themes created through the thematic analysis process of interview data, and it should be noted that the interviews were conducted as part of a larger analysis of UK college education which included the investigation of other aspects such as curriculum choice, and best practices for teaching computing, not just for the identification of the challenges, context and goals which are the aim of this paper. Therefore, just those themes which are relevant will be presented, and those regarding challenges were based on the following areas:

(1) Evolution of technology
(2) COVID-19
(3) Lack of funding
(4) Lack of experienced staff
(5) Problems of secondary education (i.e. pre-16 education)
(6) Lack of time
(7) Lack of resources
(8) Student issues

However, before these challenges are explored in greater depth, we must go back to the fundamental question of *'What are the goals of computing education?'*, and explore what these interviewees view as the goals, since their perceptions of this, can interpret what they view as challenges. These goals of computing education sit within the final stage of Biggs 3P Model; product, since this refers to the nature of outcome and what the product of teaching and learning should be [6].

### 4.1 Goals of Computing Education and UK Education Policy

Interestingly, many interviewees implicitly referenced goals that are akin to that of Bildung, which are more typical of Nordic-European countries due to the emphasis of education to be in relation to their culture [43], or one's role in life and society [34]. For instance: *"I think one of the most important thing is making them [students] aware digital citizens."* – Principle

*"I'm teaching people how to learn, not teaching them a thing... Student's should be taught how to create their own solutions."* – Computing Lecturer

*"I always say the students I'm not really teaching you particular skills in units. So yes, there are 30 units to have that they're basically the vehicle in which to allow them to understand how to learn."* – Computing Lecturer

These perceived goals of computing education are very different to simply stating an explicit aspect of content, such as a student becoming competent in a specific programming language such as Python, or C++. Instead the focus is on a student's ability to learn, reflect and act upon a situation. Similarly, many other interviewees discussed aspects such as developing a student's 'soft skills', or 'employability skills', not just the technical content involved in a computing course. However, due to the nature of many UK curriculum requirements, which often cover a wide range of content, and are often exam-based, the goals of computing education can shift towards ensuring students pass the course successfully as opposed to developing these other skills. Colleges receive funding by qualification and whether the qualification is passed, and therefore due to the general lack of funding by the UK government to support colleges [5, 30], combined with trying to meet the needs of the UK's regulatory body in assessing education standards (Ofsted - Office for Standards in Education), assessments and exams stop being used as indicators of learning, but instead the goals themselves [26]. There is more to computing education than simply knowing something or being able to do something [34] but the UK education system is not distinctly in line with these goals.

This issue is heavily influenced by government policy, that would influence every college within England, not just those who were interviewed. Unfortunately, for those that operate in the UK further education sector such as colleges, they have been subject to continuous and often contradictory policy and institutional changes [24, 27], with the sector as a whole being described as lacking a coherent education philosophy [21]. For computing educators, this can only exacerbate problems. The issues surrounding policy in the further education sector has been longstanding over decades, with some authors describing the issue of 'policy churn' [24] where there are too many changes. One experienced interviewee discussed this very issue of UK education policy:

*"If you look back over time, a new government comes to power, whether that of some shape or form, and likes to start from a point where it's all broken, and we're going to fix it. And we're hope, funnily enough, we'll fix it just in time for the next general election... If you look at the number of changes that they've [Germany] made in that time period, I think they've made two in 25 years, to what they do. And we've made nearly 25, or something ridiculous."* – Principle and Chief Executive Officer

When considering English education policy, it is clear how policy makers have tried to implement quick-fix solutions that can have an immediate political impact [10]. This is often driven by whatever the government's latest priorities are to react to problems or skills gaps, with T-Levels being just the latest in the long history of qualification reforms to be pushed forward [27]. There are perhaps lessons to be learnt from other countries regarding education policy implementation, with other countries such as Germany or Finland being more consistent and clear, and overall more critically informed [10]. Either way, from an English context, policy is impacting on college computing education.

## 4.2 The Macro-Environment

Interviews revealed that there are contextual factors that are in fact challenges themselves, but they can lead into and cause other issues. These are generally macro-environment factors that are external to a college, but as a college operates under the context of these macroenvironment factors, they are directly influenced by them. Policy changes as previously discussed is one of these factors, but two other areas identified by interviewees were that of the evolution of technology and unforeseen circumstances such as COVID-19. Colleges have no control over these factors but can merely react to them. The key challenge stemming from the evolution of technology cited by interviewees was that of 'curriculum lag', where curricula covers content that is out of date due to the rapid rate of change that exists within computing.

*"What I find is that what we're delivering here, or in the education sector is always behind the industry."* – Computing Curriculum Manager

Again, you can refer to the key question of what the goals of computing education should be, and if it is 'Bildung', then surely the latest industry standards do not matter that much. On the other hand, another interviewee discussed how industry does not know what they want, which only adds to the debate on what the goals of computing education should be.

Still, the evolution of technology had some profound changes that helped colleges when another challenge arose; COVID-19. This global pandemic caused colleges to incur costs in supporting students with online learning, while identifying best practice in this unfamiliar mode of education for computing was not a simple process.

*" It sounds that it ought to be self-evident in that IT would be really nice, easy thing to teach remotely. But actually, if somebody's writing an accessor, Microsoft access application, and it doesn't work, then the leaning over your shoulder and saying, i.e., 'you've got a comma there and not a dot' is a lot easier leaning over their shoulder than it is trying to do it on a chat box or on the forums. So that's, that's pretty challenging."* – Dean of Digital Faculty

Overall, the impact of COVID-19 on education is not a surprise as it influenced everybody worldwide in one way or another. For computing teachers, it was more specifically concerns about how to teach certain topics such as programming [12]. However, the overall implication is that there are macro-environmental factors beyond an institutions control, but what they can control is how to react.

## 4.3 Biggs Presage Factors: Student

Now that the goals of computing education, policy and the macroenvironment have all been explored, we can refer to the 3P Model, to assess what challenges of computing education are situated in its different aspects. Focusing on the student presage factors, there were two themes created from the interview data that directly relate to this; problems of secondary education (i.e. pre-16 education), and student issues. As identified in existing literature, colleges have learners with a wide variety of backgrounds and experiences, but this diverse nature of students can bring pedagogical challenges for computing educators [17, 44]. Some interviewees discussed the challenges of student motivation from having to be there (i.e. in compulsory education), some explained how some students did not truly realise what a computing course involved, but the main issue was surrounding the students previous educational background, such as whether they had studied a computing subject before. With some students having studied computing, and others not, this causes a huge disparity in student ability, and even if two students have studied computing, they may have been taught it to various degrees of quality or in different ways, with different expectations.

*"In this area in particular [computer science], the teachers don't have the skills to teach them the stuff that they need to teach you in school. So then we're basically teaching them again."* – Course Leader

*"Not a lot of our secondary schools in our area deliver computing. So they come to us and there's such a big gap from them not doing GCSE."* – Curriculum Manager

*"I think some people are very, very good coders, and some people really struggle. So there's a natural differentiation."* – Computing Lecturer

*"The habit of secondary schools... Of what I would describe as over-scaffolding learners"* – Dean of Digital Faculty

These comments are unfortunately not surprising from an English context. For example, it has been reported how students have different experiences of programming at GCSE [11, 35, 41], while a student's previous teachers can be the factor influencing any misconceptions students may have in the subject [31]. Further, the concept of 'over-scaffolding' is particularly interesting, where schools give too much structure to students at the expense of independent thought. With education policy resulting in a greater focus on grades than learning, again this comes as no surprise. However, students bring these expectations of being 'told what to do' into their future study and employment.

## 4.4 Biggs Presage Factors: Teaching Context

The other presage factor is that of the teaching context, which is perhaps broader in consideration as it involves the teachers past experience and views, in addition to curriculum, and methods of teaching and assessment [6]. Curriculum has already been highlighted as something that in the UK is expansive, with college lecturers having to teach a variety of different types of computing courses. Curriculum will also often dictate assessment and teaching methods, especially where there is a blend between study and practical based work experience. Teachers on the other hand, are particularly interesting, with the analysis of interviews suggesting that those colleges which have fewer problems with their computing education, have educators who are experienced, work well together as a team, and are proactive in keeping up to date with the latest technology. On the other hand, a main theme created which was a challenge is that of a 'lack of experienced staff'. This appears to be the case for two main reasons. First, that there is a general lack of computing educators in the sector, and secondly, how the current staff that are employed do not have sufficient skills, knowledge, and expertise for teaching computing effectively.

*"We can't explain to you how difficult it is to get teachers for computing work. Often, you know, I think, our longest job advert of 18 months for a computing teacher, and we did still didn't recruit"* – Curriculum Manager

*"I'm on a comfortable salary. But my salary would be doubled if I went in industry to what I'm teaching effectively"* – Computing Lecturer

*"We would expect teachers that are fine, that should be comfortable with coding or networking or something like that, but they're not, really not."* – Curriculum Manager

As likely influenced by education policy and English society or culture over time, there has been a lack of appropriately skilled staff for the sector, but also more specifically for computing [41, 44, 46]. With skills gaps in society for computing, those with the knowledge of the subject can earn substantially more in industry than in education. However, this only compounds the issue, as fewer quality educators leads to poorer student outcomes, and hence an even smaller pool of potential future educators entering the sector.

The UK government are offering bursaries to encourage people to enter the profession, but the impact of this will only be seen over time. Furthermore, just because someone enters the teaching profession, that does not mean they will stay in it, with interviewees citing issues such as a difficult work-life balance and a stressful working environment. It is the general lack of teachers in the sector for computing that later causes an issue of current staff knowledge as teachers from other subjects get asked to teach computing, or existing teachers in the subject area end up teaching beyond the hours they should, resulting in insufficient time to keep up to date with the latest changes in technology.

## 4.5 Biggs Process Factor: Task Processing

The final aspect of Biggs 3P Model is that of task processing, which refers to how to go about the process of teaching and learning. Both the presage factors influence this, but so does the macroenvironment factors. Importantly, in the context of computing education, there were three themes of challenges which can be mapped onto this stage of the 3P Model: a lack of funding, lack of time, and lack of resources. A lack of funding is not just a sector wide issue for UK colleges generally, but for computing specifically as it impacts on the ability to update or acquire new resources, which are crucial in such a rapidly changing subject area. Teachers need appropriate equipment and software to deliver curricula effectively [16], but this is often not the case as identified in both literature [5, 41], and by interviewees.

*"I think the other challenge, I think, is probably a technical one, because software and more particularly hardware change. So one of the big issues, I think is getting the right hardware, because it costs lots of money. And I'm going to plea that colleges tend not to be funded particularly hugely for things."* – Computing Lecturer

*"we don't have the software to go like full out... So there's kind of a limitation to what your resources will allow you to teach and what your skill set allows you to teach."* – Computing Lecturer

To mitigate some of these issues, some lecturers bring in their own equipment, although this is often also done because of poor college infrastructure, or having college security policies in place that restrict the ability to teach computing curricula appropriately, an already cited issue [2, 35].

*"I've actually just brought my gaming laptop from home and I and a really long HDMI cable, plugging that directly into the projector bypassing my college regulations, because it's the only way that I can actually teach the content they need to know."* – Computing Lecturer

*"I would say IT departments and security infrastructure, impedes and impacts on our being able to do our jobs."* – Course Leader

These challenges only add to the problem of a lack of time faced by college computing lecturers. Many explained how they are already struggling to teach the required guided learning hours that courses require, due to having to balance so many roles and responsibilities. Overall, these issues of time, resources (infrastructure, equipment, software etc), and funding all influence the process of teaching, and hence would all affect the nature of outcome (goals of computing education) in some shape or form.

# 5 DISCUSSION

## 5.1 Comparative Education Systems: The UK and Finland

While the findings presented were framed in relation to Biggs 3P Model, they were all under the context of the English education system and UK education policy. This local country context is likely to have a great influence on the different aspects of the 3P Model. Therefore, to aid the discussion in revealing the extent of the influence this country context can have, another countries education system and education policy will be used for a comparison. Education can be described as a culture-dependent phenomenon, with some of the Nordic countries for instance having a great emphasis on welfare with education seen as a way to improve living and cultural standards [29]. Finland in particular has been highlighted as a country, which unlike the UK, has exhibited patience in implementing educational policy [10]. They have also achieved high performance ratings in international testing [22], and have one of the best rates of workforce proficiency with computer capabilities [15].

Finland's education system has not changed much since the 1970s, when the Finnish parliament passed the Comprehensive School Framework Law in 1968 to create their comprehensive school model [23]. This basic model of education still stands today and is comprised of nine years of study [23], and is for those students aged 7-16. This education system, also known as peruskoulu, is compulsory for students and once complete students have a choice between general or vocational education [22]. The fact that peruskoulu is still the same model of education five decades later from when it was created is testament to its effectiveness. In fact, the OECDs Programme for International Student Assessment (PISA), which Finland has frequently ranked highly [10], explained in the 2018 report that the highest performing countries moved away from an educational model where students were stratified into different types of schools, with different curricula and requirements, to a model where all students go to schools with similarly demanding curriculum [33]. Finland was the first country to adopt this single structured approach in the 1970s [33], and it significantly differs to the UK education system where students attend primary school for ages 5-11, and thereafter attend secondary school for ages 11-16.

The change in Finnish education structure demanded a change in teacher education so teachers could effectively accommodate for such a wide range of students ages and needs [22]. This has resulted in high demands for teacher education programs with an emphasis being placed on scientific research and professional practice so that teachers leave their study with the knowledge and skills required to operate independently as both teachers and as academic professionals in developing their fields [22, 23]. Consequently, it is commonplace for Finnish teacher education to include a master's degree, with the profession being highly valued, and entrance to teacher education programmes being reported as being as low as 5% [29]. Due to this approach, Finland was ranked as the second highest OECD country in terms of percentage of teachers with at least a master's degree at approximately 90%. Meanwhile, the UK came 51st with approximately 20% [33]. With such a difference in the structure of education and the nature of experience teachers in Finland must have to enter the profession, this would significantly influence the 'teaching context' of the 3P Model.

The differences in education systems do not stop there; Finland does not have the amount of frequent testing that is found within the English education system, with the belief this could create opportunities for biased teaching [22]. This allows schools in Finland to focus more on the teaching and learning, as opposed to a focus on student grades which in England, are typically used as indicators of a school or colleges success. Furthermore, Finnish teachers spend less time teaching in the classroom than other countries [33], with middle school teachers averaging around 600 hours annually [22]. For comparison with an English perspective, one college principle which was interviewed stated how the teaching hours for their staff is around 864 hours annually. While this may not be the 'average', it certainly impacts on a teachers time for other tasks such as professional development. Therefore, as Finnish teachers spend less time teaching, this means they can spend extra time on improving their teaching practice, and developing more effective curricula and assessment [22].

A brief review of Finland's education system and policy reveals significant differences to that which exists in England, and this country context is likely to have a major impact on all three aspects of Biggs 3P Model. Therefore, regardless of only interviewing those from an English education context, it can be assumed that asking the same questions to those working in the Finnish education sector would likely yield very different responses regarding their experiences and perceptions on computing education.

## 5.2 The Fourth P of Policy

Finland and England have some similarities in computing education. Both teach information and communication technologies within their primary education [9, 41], and while the curriculum reform in 2014 in England placed an emphasis on computing, this led to an increase in momentum for reforms in other countries to focus on the concepts of computer science, programming and computational thinking [7]. For instance, within Finland, they introduced a new curriculum in 2016, where all pupils would learn basic programming and algorithmization as separate skills [9]. However, through the comparison of Finnish and English education systems, it is clear how policy has had a major impact on its direction and effectiveness with Pirhonen and Rousi [29], stating that "Educational systems, cultures and practices vary across cultures. Common to them is that they have a political dimension". Therefore, when assessing the challenges of computing education through the lens of Biggs 3P Model of classroom learning, the influence of country context and culture should not be neglected, and therefore it is proposed that there should be a fourth P of Policy. Hence Biggs 3P Model has been recreated in the context of computing with the additional aspect of Policy being added (see Figure 1).

From Figure 1, it can be seen that there are two Policy factors; government priorities, and regulatory bodies. Government priorities very much link to what a countries focus is regarding their society, and therefore linked to the emphasis and role they place on education. For example, is the focus of education on addressing skills gaps in society, through an emphasis on work-based study or 'digital skills', or is the focus on developing the right attitudes and behaviours of a countries future adult citizens? Not only does this bring to contention the goals of education once more, but the actual discussion of education terminology

internationally can cause some confusion in terms of what 'education' is and means. For instance, it has been noted how in Finnish language there can be two words used as a translation for education; one with similar connotations to that of schooling, and one with connotations referring to 'the science of upbringing' [29]. Of course, a debate on language, terminology, and connotations are not the focus of this paper, but when comparing one country to another, the differences should at least be acknowledged since they influence the inferences drawn from any analysis. Therefore, it is important that research is conducted in the context where it is applied, and caution is necessary if attempting to generalise elsewhere [6]. This gives further justification of why government priorities should be an inclusion in Figure 1, and that just because education policy seems to be effective in Finland, other countries should not seek to simply imitate or borrow one aspect of their system without taking into account all of the components involved [22]. Overall, regardless of what government priorities are, these priorities will influence all of the other aspects of the model, since they influence the student, the teaching context, the execution of the curriculum (task processing), and the nature of outcome. The other factor they influence is the number and power of regulatory bodies that exist within a country, and this is the second policy factor.

Regulatory bodies are influenced by government and often created to manage and keep track of educational performance and standards. These regulatory bodies also influence the traditional aspects that exist within the original 3P Model, and this is very easy to see from an English context. English colleges have to comply with a plethora of government regulations, resulting in many operating the same despite their legal independence [27]. They are constrained by the monitoring of their educational standards through Ofsted, their funding is dictated by the Education and Skills Funding Agency, their teacher status is monitored by the Education and Training Foundation, and as previously discussed, they are susceptible to the consistent and ever-changing amount of policy changes and regulations which exist [24]. Crucially, the two policy factors are not just important for the model of classroom learning for K-12 computing education, but for all other subjects too.

## 5.3 Computing Education and Presage, Process, Product

A more specific emphasis for computing is placed on the 'traditional' aspects of the 3P model, with student presage factors including whether a student has studied a computing subject before, their programming experience (including languages), their ways of thinking, learning and conceptualising computing topics, their expectations of what a computing course involves, and their overall interest in computing and technological developments. Hence, it should also be recognised that students may learn different aspects of computing outside of the classroom in either semi-formal and non-formal settings, and while not explored in this study, they are key contextual factors which would likely influence and form part of the student presage factors.

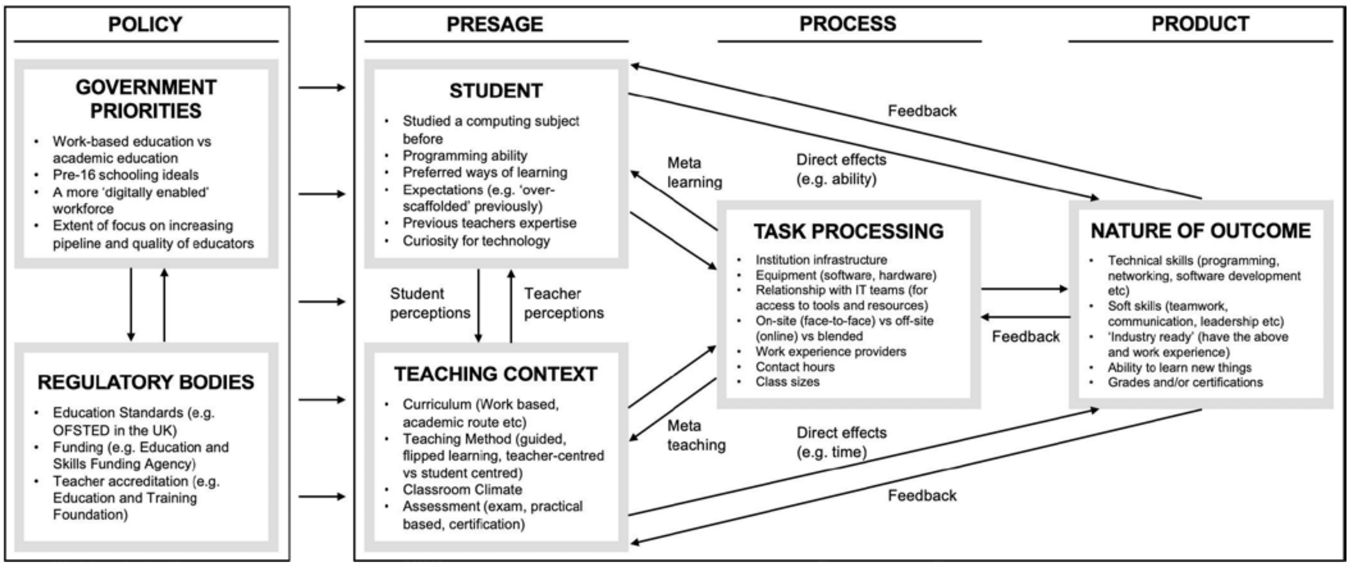


Figure 1: 4P Model of Classroom Learning. Adapted from [6]

These same factors apply to teachers too, with added aspects such as their initial teaching training and professional development being two other key influencing factors. The teaching context is a product of its environment and so curriculum choice, methods of teaching and assessment all contribute with the teacher to create this. However, they are influenced from within; from student demand, what a teacher thinks is most appropriate, and institutional ways of doing things. Together these aforementioned factors influence task processing, and for computing education, key contextual factors such as infrastructure, equipment (hardware and software), access privileges, and method of teaching (i.e., online, or face-to-face) all influence how a computing curriculum can be taught due to the heavy emphasis and need for technology in the subject. Once more, all these factors lead to the nature of outcome which for computing can be described as particular knowledge of software tools or a specific programming language, or a variety of 'soft skills' such as report writing or team working. Another desired outcome could be students that are ready for employment, but again this in context dependent, or it could be attributes aligned to that of Bildung, where students gain the ability to develop their own capabilities, together with self-fulfilment and individualisation [34]. Either way, what Figure 1 provides is a way to view some of the contextual factors which influence and can create the challenges which exist in computing education.

# 6 CONCLUSION

This paper aimed to answer the research question of *'What are the contextual factors that create the challenges that exist in computing education?'*, and through a combination of interviews, existing literature, and an analysis of the differences between the Finnish and English education systems and policy, it is clear there are a number of contextual factors that create challenges for computing education, as shown in Figure 1. On a macro-environment level, technological innovation creates new advances and tools, but as a

computing teacher, keeping up to date with these changes effectively can be difficult. Meanwhile, COVID-19 is a prime example of an external factor that nobody could have planned for appropriately which caused a cultural shift to online teaching and learning. A countries cultural and societal expectations also influence all aspects of education, and greatly affects a countries educational policy, and hence its educational system and associated regulatory requirements. On a level closer to that of the teaching and learning environment, a student's background, experience, and expectations influence how they act in a classroom with key aspects being whether a student has studied a computing subject before, or their level of programming knowledge. The same can be said for that of teachers, with curricula, teaching methods and assessment being dictated not only by a teachers formal training, but also through the ongoing development of computing education practice within their educational institution and within wider society, and what the role of computing education is predicated to be. All these aforementioned factors influence the execution of the curriculum, which in turn influences the nature of outcome, or in other words, achieving the goals of computing education.

## 6.1 Implications for Practice

Many challenges have been acknowledged as existing for computing education and educational institutions more widely but what is often neglected is the contextual factors which cause these challenges. This paper has identified what some of these contextual factors for computing education may be and through this understanding, practitioners and policy makers can seek to be more proactive and address these issues at the source of what creates the challenges, as opposed to simply taking reactionary measures.

These contextual factors vary in scale from macro-environment trends to misconceptions brought upon from an individual student's previous educational experience. Consequently, it should be recognised the extent to the variety that will exist contextually from one country to another, from one educational institution to the next, and even within individual educational institutions, the difference between different teaching approaches, curricula, resources, and students from one class to the next. Therefore, there is not necessarily a 'one size fits all' approach when seeking to address any of the challenges identified.

A key implication for practice stemming from the discussion in this paper is the difficulty in defining what the 'product' or 'nature of outcome' should be for a computing student. This brings in to questioning *'What is computing education?'*, *'What are the goals of computing education?'*, but also *'Why are goals of computing education the goals of computing education?'*. These are important philosophical questions with their respective answers dictating how educational systems and policy should be structured, in addition to how curricula, teaching methods and assessment should be designed and delivered. These questions also bring to light the further question of who decides what the appropriate answers are? Is it education providers that dictate what computing education is and should be about, or should it be society as a collective? Education is not a universal concept, and although there is a general consensus that the objective of education is to provide students with the skills and knowledge necessary for living in the future world [29], with computing evolving and changing at such a rapid rate, there is a wider discrepancy in identifying what those skills and knowledge requirements actually are.

Therefore, for any computing program of study, practitioners and policy makers must first identify what their goals are for computing education, and then work backwards in designing the curriculum, assessment, and suitable teaching methods for these goals. These goals should be communicated with all involved so there is a shared understanding of what is trying to be achieved, as otherwise there may be a misalignment in expectations and behaviour, which could ultimately impede the achievement of those set goals. To echo Schulte and Budde [34], 'Teachers and students should be able to question the setting in class and see an implication for their lives', or in other words, there must be a shared understanding and purpose for computing education.

## 6.2 Implications for Research

A limitation of this paper was that there was no primary research conducted for the country of comparison; Finland. Therefore, it is recommended that the primary research which took place regarding English colleges is replicated in a Finnish context, with Finland's college equivalent being the subject of inquiry. This is so a more effective comparison of computing education between the two countries can be made. Meanwhile, computing students' perspectives regarding the challenges of computing education would likely have provided another interesting view for discussion.

Nevertheless, the mapping of computing contextual factors to Biggs 3P Model in the creation of Figure 1 provides an insight into how the challenges and contextual factors influence each other and ultimately, student outcomes. That said, Biggs 3P model is not the only model that can be used to understand educational context. The Darmstadt model, originating from a working group of the ACM conference Innovation and Technology in Computer Science Education (ITiCSE), considered five case studies from five countries regarding how preconditions, circumstances and influence factors play a part in computer science education for a variety of educational relevant areas [19]. As future work, both the English and Finnish education systems could be evaluated in the context of the Darmstadt model for further analysis and understanding of the context factors influencing computer science education in these countries.

In addition to the creation of the 4P Model, the interview findings in particular make a key contribution to research since they were based on colleges in the English further education sector which has typically been a neglected area of research [5, 25]. Hence, providing a deeper understanding of the challenges that exist for computing education in this sub-context. Together, these findings, in combination with a discussion surrounding two different education systems, lay the foundations for further studies in two main areas. First, given the emphasis on context that has been shown to influence computing education, practitioners and policy makers should reflect on the challenges that exist for computing education in their jurisdiction, and what the root causes are, so they can address them at the source. Secondly, this paper has provided an ongoing debate, but with no clear answer as to what the goals of computing education should be. It is clear through the created model that all aspects of the model ultimately lead to affecting student outcomes, but without defining what these outcomes should be, how can any curriculum or computing program of study be designed effectively. Therefore, further research should seek to explore this philosophical question in greater detail and what computing education is and should be over the following years or even decades.

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