# Understanding professional learning for Computing teachers from the perspective of situated learning

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**ABSTRACT**
Situated learning theory maintains that there is a relationship between learning and the social situation in which it occurs; learning is embedded in activity, context and culture. In terms of professional learning for teachers this implies that effective learning takes place within a community where experts and novices meet and where practice is modelled; such a community needs to be deeply relevant to every day practice in the classroom. In this paper we discuss Computing At School, a grass-roots organisation that has grown up over the last ten years through teacher communities, and also with broad support of academia and industry. In a time of increased interest in the inclusion of computer science in school curricular, Computing At School is a community of practice of all teachers affected by curriculum change in Computing, and models an innovative approach to professional learning that is based on community and support. We describe here how Computing At School draws on situated learning theory to contribute to the development of Computing in the curriculum, evidencing both the journey and lessons learned.

**KEYWORDS**
situated learning, community of practice, computer science education, professional learning, K-12 education

## 1. Introduction

The arrival of Computing in the school curriculum brings with it the need to equip teachers with the skills and knowledge that they need to deliver it effectively. A recent article by Yadav and colleagues in this journal (Yadav, Gretter, Hambrusch, and Sands, 2017) explored comprehensively the need to support teachers in the area of professional development (we prefer to call this *'professional learning'*(PL) which is a term which supports more ownership by teachers rather than development via another's agenda). Another recent review of teacher professional learning looked at a range of studies from the USA (Menekse, 2015), highlighting that many were short summer programmes, some as short as one week. Menekse commments on the lack of active learning in these programmes. On the other hand, there are other initiatives that focus on teacher collaboration and development of teacher networks (Cutts, Robertson, Donaldson, and ODonnell, 2017; Goode, 2007; Morrison, Ni, and Guzdial, 2012; Ni, Guzdial, Tew, Morrison, and Galanos, 2011; Sentance, Humphreys, and Dorling, 2014; Thompson, Bell, Andreae, and Robins, 2013). Within Computing At School (CAS), a grass-roots organisation for supporting Computing teachers in the UK, professional learning is

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built around community and peer support (Bradshaw and Woollard, 2012). Goode describes the provision of workshops in computer science and pedagogy and notes that these enable teachers to develop their own small networks of support (Goode, 2007). Morrison et al (Morrison *et al.*, 2012; Ni *et al.*, 2011) adapted the originally university-focused Disciplinary Commons (DC) approach (Fincher and Tenenberg, 2007; Tenenberg and Fincher, 2007) to be used with school teachers, by providing monthly meetings to discuss issues of teaching and curriculum over a period of a year. The CAS and DC approaches are much more aligned to our current understanding of what makes good teacher professional development than subject-focused workshops.

Computing PL initiatives can draw on the substantial amount of general research on teacher professional learning, particularly with regards to the relative effects of different types of PL for teachers and what effects positive change. There is considerable evidence pointing to the fact that teacher PL should involve collaboration and be sustained over time (CUREE, 2013; Guskey and Yuon, 2009)), as well as be connected to academic teaching and learning:

> "Effective professional development is intensive, ongoing, and connected to practice; focuses on the teaching and learning of specific academic content; is connected to other school initiatives; and builds strong working relationships among teachers." (Darling-Hammond, Wei, Andree, Richardson, and Orphanos, 2009, p.5)

In 2016 new guidance on teacher professional development was released by the department for education in England (Department for Education, 2016). The guidance took the form of a five-point standard which drew on available evidence around professional development. The five aspects of the standard are:

(1) Professional development should have a focus on improving and evaluating pupil outcomes.
(2) Professional development should be underpinned by robust evidence and expertise.
(3) Professional development should include collaboration and expert challenge.
(4) Professional development programmes should be sustained over time.
(5) All this is underpinned by, and requires that, professional development must be prioritised by school leadership

It is clear from the research on teacher PL that lasting change is not going to occur as a result of one-week summer programmes far away from the school situation. This research evidences a move towards constructivist and situative approaches to education, grounded in classroom practice and delivered within professional learning communities (Borko, Jacobs, and Koellner, 2010). It also points to the importance of communities of practice (Lave and Wenger, 1991; Wenger, 2000) as a means of facilitating collaborative and sustained professional learning. Several CS-focused papers refer to the development of communities of practice for Computing teachers (for example, Goode, Margolis, and Chapman (2014); Kolikant and Pollack (2004); Ryoo, Goode, and Margolis (2015); Yadav *et al.* (2017)) and this includes our own work about the Computing At School (CAS) community (Sentance and Humphreys, 2015; Sentance *et al.*, 2014). However this is rarely linked to the theoretical perspectives of situated learning from which the idea of a CoP originates. Situated learning theory explains how participation in the CoP occurs and changes over time; we consider that this is important in trying to understand how teachers can become effective Computing teachers.

In this paper we discuss how professional learning for teachers within communities

can be informed by a greater understanding of situated learning theory (Lave and Wenger, 1991). In particular we set out to explore one key question: *'How can professional learning for in-service teachers of Computing succeed?'*. In answering this question we relate the experience of Computing At School (CAS) to situated learning theory and make recommendations for others in a similar position. CAS uses an integrated approach that meets teachers where they are at and does not extract them from their current situation (Sentance, Dorling, and McNicol, 2013); this is based around peer support and professional relationships.

In the next section we will review situated learning theory before providing an analysis of the CAS approach from a situated learning perspective.

## 2. Situated learning

> "A theory of social practice emphasizes the inherently socially negotiated character of meaning and the interested, concerned character of the thought and action of persons-in-activity." (Lave and Wenger, 1991, p.50)

While conventional explanations of learning imply that learning is 'cerebral' and happens to the individual, situated learning takes the view that "learning as increased participation in communities of practice concerns the whole person acting in the world" (Lave and Wenger, 1991, p. 49). This theoretical perspective acknowledges that cognition, meaning and knowing all have a dependency relationship with the world, the person involved and the activity. While Lave and Wenger draw on examples of apprentices in various industries as exemplification, Putman and Borko's work enables us to understand the relevance of situated learning to teacher professional development (Putnam and Borko, 1997, 2000). For example, situating learning does not mean that all teacher learning opportunities must take place within the classroom, but that the context of the learning is situated in their experience:

> "..the situative perspective holds that all knowledge is (by definition) situated. The question is not whether knowledge and learning are situated, but in what contexts they are situated. For some purposes, in fact, situating learning experiences for teachers outside of the classroom may be important-indeed essential-for powerful learning"(Putnam and Borko, 2000, p.6)

Within situated learning theory there are three important concepts. Firstly the idea of the *community of practice*(CoP) emphasises the importance of relationships in learning. Secondly, the notion of *legitimate peripheral participation*(LPP) acknowledges that learners move from novices to experts in their assimilation into the CoP. Thirdly, there is a conflict between newcomers and old-timers that Lave describes as *continuity-displacement* as new ideas replace old and the community evolves.

### *2.1. Communities of practice*

Lave describes that being a member of a CoP shapes newcomers' identities and in the process gives structure and meaning to knowledgeable skill (Lave, 1991).The concept of the CoP has become popular and been applied to a wide range of domains, not just education. According to Wenger, to be in a CoP is to have a joint enterprise, mutuality and a shared repertoire of communal resources (Wenger, 2000). In practice, teachers working together towards a common goal, for example, implementing a new strategy, who share their experiences, talk the same language, and are willing to learn from

one another, can be said to be a CoP. Wenger presents the CoP as a 'social learning system' (Wenger, 2010).

As Wenger develops his work on communities of practice he outlines that membership of a CoP is built round certain competencies including an understanding of what matters to the community, being able to engage in the community, and being able to use resources the community has accumulated through learning (Wenger, 2010).

Another aspect of a CoP is that it has a learning curriculum and not a teaching curriculum. A teaching curriculum is constructed for instruction of newcomers, mediated through an educator. In contrast a learning curriculum has opportunities for learning in actual practice:

> *"A learning curriculum is a field of learning resources in everyday practice viewed from the perspective of learners"*(Lave and Wenger, 1991, p.97)

A learning curriculum is necessarily situated and is a characteristic of a community. This is a key to our understanding of the CoP within teacher PL.

### *2.2. Legitimate Peripheral Participation*

Within Lave and Wenger's CoP we have those who are newcomers, and those who are 'old-timers'. Some may be 'apprenticed' cognitively, referring to the learning that takes place between an expert and a novice within the CoP. The idea of being a newcomer and not yet a full part of the CoP is described as *legitimate peripheral participation*. Legitimate peripheral participation (LPP) refers to the existence of newcomers who are not yet fully participating in the community but who are watching from a safe distance (Lave and Wenger, 1991, p. 29). However LPP is not merely observational. Participation is a way of learning: of both absorbing and being absorbed in the "culture of practice"(p.95). LPP is illustrated by Lave and Wenger by stories of apprentices, although they are clear that situated learning is not just an abstracted view of apprenticeship (p.37).

The notion of LPP can be either empowering or disempowering. This is an important aspect of the theory as disempowered teachers may feel resentment at their position in a community that they have not chosen to join. For many they have recently become part of the CoP by default and not by choice:

> "Legitimate peripherality is a complex notion, implicated in social structures involving relations of power. As a place in which one moves toward more intensive participation, peripherality is an empowering position. As a place in which one is kept from participating more fully - often legitimately it is a disempowering position" (Lave and Wenger, 1991, p. 36)

This provides a useful perspective with which to understand teachers having to learn to become Computing teachers. Being a legitimate peripheral participant may be comfortable or uncomfortable, but access to professional learning and reflection on experiences in school can enable them to move to a position of more central participation.

### *2.3. Continuity - displacement*

Another characteristic of a CoP is that it will change and reproduce itself. Lave and Wenger report that CoPs are *"engaged in the generative process of producing their own future"*(Lave and Wenger, 1991, p.57). Lave talks about 'cycles' and a 'changed

understanding' in the way that newcomers become old-timers and new newcomers join with new ideas - an iterative process (Lave, 1991).

The change that newcomers bring to the community is described as *continuity-displacement*. This stimulation of new knowledge and the impact on the 'old-timers' can disrupt existing practices (Ellis, 2007). Newcomers bring conflict because of their perspectives:

> "Granting legitimate participation to newcomers with their own viewpoints introduces into any CoP all the tensions of the continuity-displacement contradiction. These may be muted, though not extinguished, by the differences of power between old-timers and newcomers"(Lave and Wenger, 1991, p.61)

The dynamic nature of communities in terms of this disruption and displacement is very relevant to Computing PL as the field is young, particularly in schools, and expertise is shifting and shared understanding changing quite rapidly.

### *2.4. Critics*

Situated learning theory was first proposed by Lave and Wenger in 1991 and has been widely influential, however it has its critics (for example, Anderson, Reder, and Simon (1996)). Handley et al argue that the journey from novice to master, or from peripheral to full participation is not straightforward when set in the context of a multiplicity of communities of practice (Handley, Sturdy, Fincham, and Clark, 2006). They also call for a need to look more broadly at the way that people identify with multiple communities of practice and negotiate their engagement with them (Handley *et al.*, 2006).

The work of Lave and Wenger drew attention to fundamental differences between educational researchers around how learning takes place and the conflict between the 'learning as acquisition' view (knowing is *having* or *possessing*) versus the 'learning as participation' view (knowing is *belonging*, *participating* or *communicating*)(Sfard, 1998). Sfard argues that the participation metaphor has *"a potential to lead to a new, more democratic practice of learning and teaching"* (p.9) but also that there is room for a middle view in which both metaphors can be partially adopted.

Little has been discussed in CS education with regards to situated learning, with the notable exception of Ben-Ari's analysis in 2004 (Ben-Ari, 2004) who considered the pros and cons of applying this approach to the CS learning of undergraduates; Ben-Ari demonstrates some sceptism but acknowledges that contextualisation is useful in the learning of CS.

Overall, the ideas of Lave and Wenger help to provide a direction for effective professional development in Computing. The premise that teachers learn in communities of practice is salient here: how teachers can be supported at different levels of peripherality in the community, and how PL opportunities are designed to allow for continuity, change and the potential displacement of old-timers. These ideas underlie the way that CAS has evolved over the last ten years, as will be described below.

## 3. Computing At School - the context

In September 2014, changes to the English national curriculum for Computing were implemented, including the removal of the subject formerly known as ICT[1] which

[1]Information Communication Technology

was replaced by the subject Computing. Computing has three elements: Information Technology, digital literacy and Computer Science (The Royal Society, 2012). The new elements of the subject for teachers are within the discipline of computer science and this is where thousands of teachers have a need for professional development to give them not only new subject skills and knowledge, but also teaching strategies, assessment support and above all, confidence (The Royal Society, 2017).

Becoming a teacher of Computing in the UK, particularly in England where the new curriculum was implemented, has been a huge challenge for many. Imagine that you are an experienced teacher in a school, feeling confident in your abilities, and then you learn that the whole curriculum subject with which you are familiar has changed to include topic areas about which you are either very rusty or have absolutely no knowledge? This is the situation for many teachers in England who were formerly ICT teachers and have been "rebranded" as Computing teachers. Thus within the community of Computing teachers there are many who are only able to engage in computer science (CS) aspects to a limited degree because of a lack of confidence and identity. In this situation the teachers will feel like a newcomer to the community of Computing teachers.

Due to the differing backgrounds of ICT teachers, no assumptions can be made of what a 'typical' teacher looks like in this context, and therefore any programme to support teachers has to be flexible and individualised. There is no 'one size fits all'.

### *3.1. Knowledge and skills needed by teachers*

It is difficult to thoroughly assess how to provide support for teachers without identifying exactly what teachers need. There is no doubt that teachers need to understand subject matter 'deeply and flexibly' (Darling-Hammond, 2008); teachers of students at the end of their schooling may take several years to acquire subject knowledge at the right level.

The aims of the new curriculum are that all pupils:

- can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation
- can analyse problems in computational terms, and have repeated practical experience of writing computer programs in order to solve such problems
- can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems
- are responsible, competent, confident and creative users of information and communication technology (Department for Education, 2014)

Children at all ages will be learning computational thinking skills, partly through learning computer programming. The curriculum includes the following strands:

- Algorithms and Programming
- Data
- Computers and Social Informatics
- Communication and Networking
- IT and Digital Literacy

Teachers who have been teaching earlier versions of the current curriculum, ICT, will have a thorough understanding of some aspects of the new curriculum but not of others. So what elements are new? The additional computer science elements can be

identified as follows:

- **Primary Computing (age 5-11)**: an understanding of computational thinking skills is highlighted in the curriculum, including algorithmic thinking. Students need to understand, create and debug programs using block-based environments, and have an understanding of how the internet and networks work.
- **Lower secondary Computing (age 11-14)**: students should develop skills in algorithmic thinking, and be able to write programs in two or more programming languages, one of them textual, including use of selection, iteration, and arrays. Students should understand how a computer processes data, how it stores text, image and sound data, simple logic, and use binary number systems.
- **Upper secondary computer science (age 14-18)**: new qualifications require students to be able to develop programs according to given specifications demonstrating competence in programming; students also learn about algorithms and data structures, data representation, computer architecture, networks, and social and ethical aspects of computing.

Of these topics, it is clear that computer programming is a skill which cannot be learned overnight by students or teachers, although we can learn from experts in how to acquire the skills needed more quickly (Norvig, 2001). A situated learning perspective can be used to understand how teachers are acquiring subject knowledge in the context of the curriculum and aligned with appropriate pedagogy. In fact, feeling pedagogically confident is key to becoming an effective Computing teacher (Ball, 2000) and it is important not to overlook how teachers develop their pedagogical content knowledge (PCK) (Shulman, 1986) around Computing. The knowledge we are talking about with relation to teachers' professional learning is not just subject knowledge about computer science (CS) topics but the knowledge needed to effectively teach and assess students from the age of 5.

### *3.2. The development of Computing At School*

A significant driver in both the curriculum change and subsequent support of teachers in England has been the organisation Computing At School (CAS), a UK-wide group. In line with the shift described above from top-down organisation-driven provision for teachers, CAS emerged from the ground up as a teacher-owned and teacher-driven organisation. The energy, creativity, and leadership came from its members, who are primarily teachers, but also come from industry, higher-education, awarding bodies and local authorities.

CAS began ten years ago in 2008 as a small group of people concerned about what was being taught in school before the age of 16. Numbers studying CS at university and at sixth-form level (Grades 11-12) were declining and what was being taught in earlier school grades was not preparing students for considering this as an academic route (Brown, Sentance, Crick, and Humphreys, 2014). As well as teachers, the first members of CAS also included representatives from both industry and academia and there was a sense of a common concern. In those early days CAS was involved in curriculum development, political lobbying and organisation of training for teachers, in general trying to advocate for curriculum change towards more computer science in the curriculum. As Brown et al describe it, at that time CAS *"seemed to fight a lonely battle against the odds"* (Brown, Kölling, Crick, Jones, Humphreys, and Sentance, 2013, p.2).

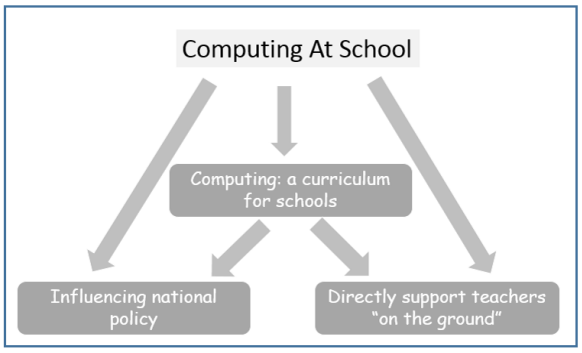


**Figure 1.** CAS activities prior to 2014

CAS has gradually evolved since 2008 into a community that directly supports Computing teachers by providing them with teaching material, training, local hubs, newsletters and the opportunity to interact with like-minded colleagues, and acts as a subject association for Computing teachers (Computing At School, 2015). Some modest government funding has enabled CAS to implement some aspects of the approach described here. Other aspects are unfunded and exist through the time and energy of members of CAS; some are still emerging and evolving.

In the next section we describe the CAS approach to PL and how it is based in a situated learning perspective on learning.

## 4. Computing At School - Community of Practice

As discussed above, Computing At School (CAS) has evolved over the last ten years as a community of Computing teachers and others with an interest or involvement in Computing education, including those in teacher training, local government, industry and public policy. Many activities take place within CAS, including the following:

- Face-to-face Networking meetings
- Subject and curriculum workshops and training sessions
- Online discussions
- Sharing of resources, by teachers for teachers
- Regular teachers' magazine
- Specialist groups, eg around inclusion and research
- Guidance on delivery of the curriculum
- Regional and annual teacher conferences
- Weekly social media 'chats'

With less than a handful of paid staff, the activities are largely led by volunteers and enthusiasts. Within the mission statement for CAS are the words:

> *" Through the participation of the wider community we seek to support and empower each other in an inclusive and self-sustaining body so that each child has the opportunity of an outstanding computer science education. CAS achieves this by supporting and promoting all those individuals, partner organisations, companies, and university departments who wish to run CAS regional hubs, put on CPD courses, generate teaching resources etc.*

*that support the Computing curriculum."*[2]

According to Wenger (2011), a CoP has three key characteristics: domain, community and practice. In the case of Computing in the curriculum, and CAS in particular, the community is formed around the teaching of Computing as a domain. The sharing of ideas, resources and expertise provides the community characteristic. Computing teachers are practitioners and have a focus on their students, facilitating learning and being a professional Computing teacher. Membership of this CoP is not restricted to teachers as others, such as those who educate teachers, or who support computing education in a voluntary way, are also members of the wider CoP, providing they share and understand the domain.

There are several communities of practice at play in CAS. At one level there is a national CoP, centred around a website that provides community discussion, resource sharing and events (Bradshaw and Woollard, 2012; Brown and Kölling, 2013; Weatherby, 2017). The online community forum also allows the community to share with each other and have help for teaching and learning (Bradshaw and Woollard, 2012). At the time of writing this community has in excess of 30,000 members (in 2012 there were 1000).

There are also ten formal Regional Centres, providing communities centred around universities (see Figure 2), and, even more locally, CAS Hubs where teachers meet after school in their community with their peers to share resources, receive training, try out lesson ideas and discuss pedagogy with each other. Since the formation of CAS, hubs have been the central point of all CAS activity (Sentance and Humphreys, 2015). They are run by volunteer teachers for teachers, and meet once a term in a local school with the shared goal that all will leave the meeting with something they can use in their classroom. Hubs are 'safe places' for teachers to work with and for each other as they share in each other's professional development and understanding of Computing. Teachers can belong to several communities of professional practice of differing sizes.

### *4.1. CAS Master Teachers: from LPP to full participation?*

In the spirit of empowering teachers and grass-roots development, the primary focus within CAS is locally available, peer-to-peer, and face-to-face support. Active teachers support others by running local, low-cost training sessions in schools. These teachers are known as CAS Master Teachers (Sentance *et al.*, 2014) and are supported by CAS Regional Centres.

A CAS Master Teacher is an experienced teacher who works with a number of teachers in his or her local community, supporting them with their teaching of Computing, particularly with the newer CS elements of the curriculum.

CAS Master Teachers are selected for their excellent subject pedagogy and outstanding classroom practice, and also for such qualities as experience in mentoring colleagues, running training sessions, and credibility in their communities. Originally the first Master teachers were the 'early adopters' of the curriculum, but as time has gone on teachers are applying to become Master Teachers who were completely new to Computing just three or four years previously. Being part of the CoP of CAS has enabled teachers to move from LPP to 'full participation' as a CAS Master Teacher. Even as a Master Teacher the teacher very often does not *feel* like an expert, and this is in line with Lave & Wenger's view that all participants are an LPP to some degree:

[2]https://www.computingatschool.org.uk/about

> *"Insofar as this continual interaction of new perspectives is sanctioned, everyone's participation is legitimately peripheral is some respect. In other words, everyone can to some degree be considered a 'newcomer' to the future of a changing community"* (Lave and Wenger, 1991, p.117)

The CAS Master Teacher offers low-cost PL events either in his or her own school, or at another venue such as the local university or other schools nearby. CAS Master Teachers also can be approached to give advice on the curriculum. Much of the training that the Master Teacher offers has been developed from actual practical experience of delivering the subject in school themselves:

> *"I help teachers with subject knowledge and help to ensure they understand the concepts prior to teaching them. I give people confidence to go away and actually use the resources. I give them the confidence to give it a go "(Bea)* (Boylan and Wills, 2014, p.13)

The CAS Master Teacher is part of the Network of Excellence (Figure 2). The Network of Excellence is the part of CAS that receives (modest) government funding[3]. The funding is distributed to CAS Regional Centres who provide training and support for Master Teachers at a regional level. The training offered by the Master Teachers will be tailored to the demands of the local community: there is no compulsion on schools or teachers to use the services of the Master Teacher, but these are advertised through the CAS community website and sent out to schools who sign up to the Network of Excellence.

From a situated learning perspective we understand that teachers can learn from those with more expertise in the community. Teachers can learn from Master Teachers and Master Teachers can learn from those running the Regional Centres. Master Teachers take on a mentoring role, which takes place in a face-to-face environment. Online training is very useful to supplement the services offered by a Master Teacher but the reassurance and confidence that a teacher new to Computing needs can be effectively realised through personal relationships.

The Master Teacher is recruited and trained by the Network of Excellence to provide support to other teachers in their region. As well as events they organise in response to local need, they can arrange visits to individual teachers or schools, to give one-to-one support around aspects of the curriculum.

The CAS community has already seen the emergence of some inspirational teachers who not only excel within their own classrooms but are willing to make significant contributions to the wider community of Computing teachers within CAS.

### *4.2. Hubs and Regional Centres*

Cascading good practice and a deep understanding of appropriate subject knowledge is a key part of the CAS Network of Excellence. Regional hubs are the core CAS activity and provide further opportunities for cascade. These informal and free meetings enable teachers to share good practice with each other and offer informal training.

In all, a range of activities take place within CAS which support teachers in different ways, as shown in Table 1. Other providers work with CAS and alongside CAS to support teachers. However, whereas other providers may put on training courses, training in discrete units is a very small part of what CAS sets out to do.

Several universities have for many years worked with teachers and Master Teachers

[3]This funding is ending in 2018 and there is a bidding process underway for another larger tranche of government funds

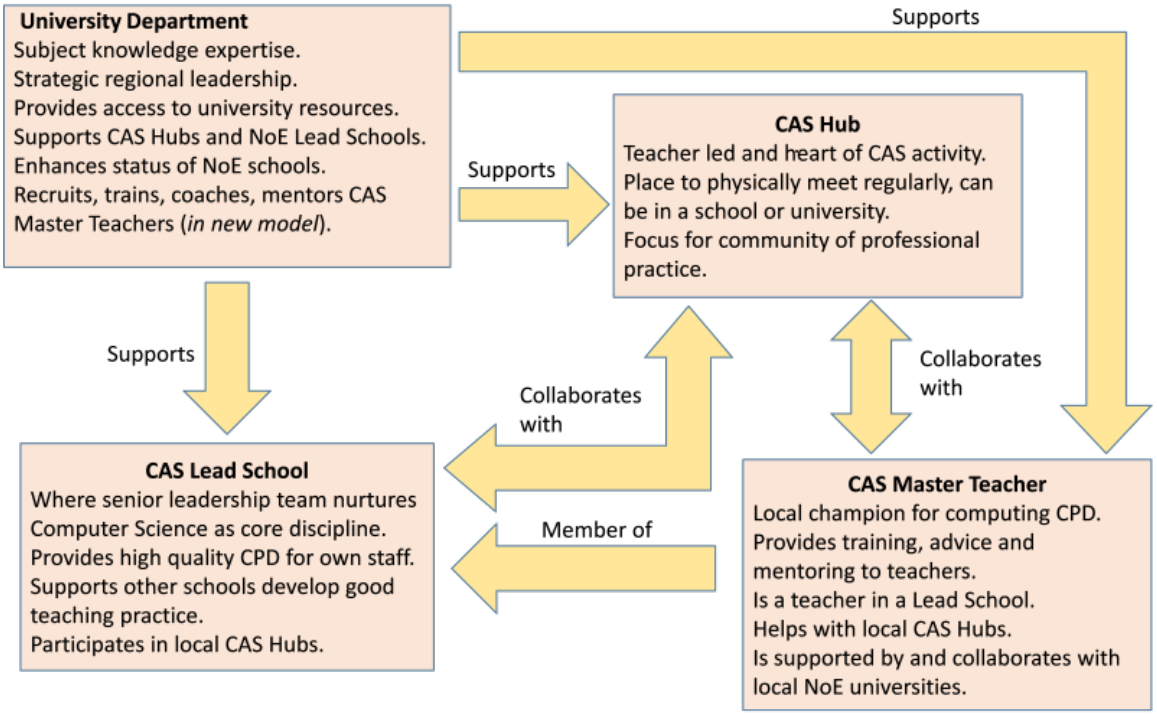


**Figure 2.** The structure of the CAS Network of Excellence

**Table 1.** Various aspects of Computing At School

| **Aspects of CAS** | **How used** |
|---|---|
| Website | Divided into forum, events and resources this is the main information source for teachers and other members of CAS. |
| CAS Hubs | Groups of teachers |
| CAS Include | Informal group focused on inclusion and diversity in CAS |
| CAS Research | Informal group to support teachers interested in research |
| CAS Regional Centres | Regional Centres of the Network of Excellence |
| CAS Master Teachers | Lead teachers supporting other teachers |
| CAS Barefoot | Resources to support primary teachers |
| CAS Tenderfoot | Resources to support secondary teachers |
| BCS Certificate | Certificate in Computer Science Teaching teachers can work towards over one year |
| CAS TV | Short videos on aspects of teaching Computing |
| #caschat | Weekly Twitter conversation for CAS members |

to offer them support and pass on their subject knowledge/experience of teaching. A recent development has seen the funding of 10 CAS Regional Centres based in universities, which has formalised the support they give. Teachers belong to a hub which in turn is part of a CAS Regional Centre. The focus and shared knowledge within these communities is continually changing as teachers become more knowledgeable, or leaders move schools and move on and new teacher-leaders emerge. One of the lessons that has been learned within CAS is that change is part of the process of the CoP: the group of Master Teachers and Hub Leaders is not static but will change over a period of years. Again this is consistent with Lave and Wenger's account of situated learning.

Hubs and regional centres demonstrate the importance of face-to-face and local support of teachers and CoP members for each other, and this is key in the development of relationships (which may then continue online). While the need of teachers was originally very strongly articulated as subject knowledge, there is a shift towards pedagogical strategies for computing, with more discussion around this in communities and more take up on professional learning opportunities in this area. This change demonstrates the evolutionary nature of CoPs as engagement changes over time.

### *4.3. The online community*

The online community of CAS is very large and can be accessed via a website divided into three parts: resources, discussions and events. It began as an email group in 2008 and has gradually evolved and scaled up in response to the number of teachers joining.

In CAS a teacher may belong to several (perhaps overlapping) communities of practice, possibly depending on size and locality - for example a teacher is a member of their school or department community, a member of a local CAS hub, and a member of the national Computing At School online community. The fact that this complicates the journey from novice to master was mentioned earlier (Handley *et al.*, 2006) and modelling this complexity may be valuable. Particularly of interest may be the extent to which knowledge transfers between communities.

Weatherby's doctoral work focused on an analysis of the online CAS community (Weatherby, 2017). She carried out interviews with a number of CAS members, as well as a larger survey, and was able to classify types of CAS members in regard to their teacher background. Weatherby found that a computing teacher's background characteristics, notably his or her professional experience prior to teaching computing, played an important role in their attitudes toward and preparedness for teaching computing as well as influencing the professional development resources to which they have access. Weatherby was able to identify change in teacher practice in terms of classroom practice affected by use of resources shared on CAS. We can infer from this the CAS online community can be described as a CoP, at least for some teachers. Weatherby herself describes CAS as a virtual community which has organic communities of practice that emerge from within it.

There are other activities within CAS. A weekly social media chat is emerging as a useful sharing of ideas and resources for many time-poor Computing teachers. The BCS Certificate in Computer Science Teaching (Sentance and Csizmadia, 2017) enables teachers to work on projects in their classrooms over the period of a year to reach a 'standard'- this could also be analysed as a way of allowing teachers to move from LPP to more central participation with increased confidence - passing the Certificate gives a teacher the feeling of belonging to the Computing teachers' community. There is a CAS Assessment Working Group, made up of teachers, who meet and discuss

issues relating to summative assessment and specifications for examinations, and a CAS Include group, a community of people interested in diversity and inclusion, who also promote and develop appropriate resources. In addition, engaging with CS Ed research is an emerging aspect of CAS with groups of teachers meeting and sharing each term.

The activities and resources within CAS together form the learning curriculum described in Section 2.1. There are a range of opportunities, both locally and on-line, for teachers to engage with and they engage teachers in actual practice. For example, a teacher may download a resource written by another CAS teacher, edit it, try it in the classroom and then upload it again for others to use.

### *4.4. The Computing-newcomer and CAS*

To be an effective CoP in Computing teaching there needs to be a way into the community for the novice teacher of Computing (who may be experienced teachers of another subject), to participate initially as an observer with a somewhat casual connection through to taking responsibility and leadership roles in that community either locally, regionally or nationally. Whilst there are no agreed steps akin to the 12-step model of working with alchoholics espoused by Lave and Wenger, activities within CAS can be positioned as a series of steps and stages that newcomers to the community can voluntarily follow; thus many teachers informally report on their move from the periphery of the community (LPP) through to a central role, even to being regarded as a leader and enabling others.

The stages can be exemplifed as follows. The first step for a teacher unfamiliar to computing would be to join the online CAS community and get acquainted with the topics being discussed as well as the manner of that discourse, accessing resources and then contributing to those discussions by leaving a comment or providing feedback on resources they have downloaded and used in their classroom. The fact that the CAS resources are aligned to different curricular in the UK enables teachers to relate what is available to their direct need at school. Attending a local CAS Hub meeting might be the next stage, though for some this may be their first encounter with CAS. The more experienced hub leader will encourage them to a further stage of engagement by sharing experiences by planning and delivering a short presentation on a topic of their choice in future meetings. A subsequent stage would be to upload the online community for wider dissemination and participation. The teacher is then starting to move from observer to participant.

Many involved in the CAS Community still remain as observers, perhaps 'lurking' in forums and accessing the resources for their own use. This is of course normal and acceptable behaviour in any online community, although the collective goal is to enable the newcomer to recognise they have knowledge and skills of value to others and that they can move move to a more central, participatory role.

A later stage for the novice teacher would be from participant to leader through volunteering to run a hub themselves or become a CAS Master Teacher, which raises their status and gives access to other regional and national practitioner CoPs. The role played by regional centres has been key in many instances for recognising those in the area who would benefit from these latter stages where Master Teacher induction and training has been provided with other Master Teachers an thus a new layer for support in the community is exposed. This has been further developed with a co-teaching model where the more experienced lead on a specific course with the new

Master Teacher contributing and teaching as well.

Over time newcomers can move from 'novice' to 'old timer' under the watchful encouragement of other 'old timers'. They have been introduced through observation to the manners and functions of the community moving to low-stakes participation either online or through the hub meetings with the final stage of leadership in their local community. The outcome is more confident teachers and better teaching of Computing in school, as will be discussed in the next section.

### *4.5. Evaluation of CAS*

A recent Royal Society report (The Royal Society, 2017) reported that CAS is the most popular 'resource' used by teachers with 36% of secondary teachers noting the support offered by CAS. However CAS has not reached all teachers in England or the UK, and the work relating to different aspects of CAS activities is on-going. A range of evaluation activities have taken place over the last ten years which give some evidence as to the effectiveness of the CAS approach.

Teachers on training courses are invited to leave feedback using an online form at the end of workshops with Master Teachers or at the Regional Centre and 10 weeks later are asked about the subsequent impact on their training, including knowledge, practice, organisation, learners, following Guskey (2000). Early results from these evaluations was reported elsewhere (Sentance and Humphreys, 2015; Sentance *et al.*, 2014). In the most recent evaluation of the effectiveness of Computing At School, survey feedback from computing teachers supported by the NoE showed that 65% of teachers report that their subject knowledge or understanding had improved, with others identifying improvements in understanding issues such as assessment, and the mean base confidence of teachers before receiving CPD was 4.1 on a 1-10 scale which rose by 3.7 points on this scale to 7.8 by the end (BCS / CAS, 2017). This continuing body of evidence demonstrates that CAS is able to offer quality professional learning opportunities that support teachers and have a subsequent impact on childrens education.

Three large-scale surveys of teachers were carried out in 2014, 2015 and 2016 by the authors and reported elsewhere (Computing At School, 2016; Sentance and Humphreys, 2015).

These surveys are conducted and advertised online and have large numbers of teachers responding. The survey design is similar each year and includes questions about CAS in general, with particular questions for teachers about their professional development, what they teach in school, and their confidence and attitudes to teaching Computing. Here we give the data from the 2016 survey, when there were 1303 respondents of which 99% of those responding were members of CAS and 78% (N=822) were teachers.

Teachers were asked to rate their confidence in the delivery of Computing on a scale of 1-10. 88% of teachers scored their confidence as 5 or more in 2016 compared to 86% in 2015 and 80% in 2014 - showing a gradual but definite increase. In 2016 teachers reported an average confidence value of 7.3. When comparing primary and secondary teachers self-reported confidence of the survey respondents was similar in both phases, with primary teachers reporting more confidence at 7 or above (81% of primary teachers compared to 71% of secondary teachers) (Computing At School, 2016). This increase in confidence within the community of teachers gives some indication of the impact of the CAS approach, although given the nature of the community it is difficult to uniequivocally identify impact.

**Table 2.** Types of professional development undertaken

| | **Training** run by MT | **Training** run by HEI | **Hub** meetings | **CAS** conference | **MOOC** |
|---|---|---|---|---|---|
| Number answering | 359 | 351 | 380 | 181 | 271 |
| Very useful | 38% | 38% | 26% | 36% | 31% |
| Useful | 33% | 36% | 34% | 31% | 35% |
| Parts were useful | 26% | 22% | 38% | 31% | 32% |
| Not at all useful | 2% | 4% | 2% | 2% | 1% |

**Table 3.** Feelings about teaching Computing (n=775) (Computing At School, 2016)

| | Agree strongly | Agree slightly | Disagree slightly | Disagree strongly |
|---|---|---|---|---|
| I enjoy teaching the computer science elements of Computing | 74% | 21% | 4% | 2% |
| I have had to work hard to develop my subject knowledge | 59% | 28% | 9% | 4% |
| I have gained confidence in teaching Computing since its introduction in 2014 | 54% | 36% | 7% | 3% |
| Generally my students enjoy Computing | 53% | 38% | 8% | 1% |
| I know where to find good quality resources for Computing | 42% | 44% | 11% | 2% |
| I find some of the concepts and programming difficult to teach | 30% | 39% | 20% | 11% |

Teachers were also asked how many hours they had spent engaging in professional development in Computing. The data in Table 2 shows which professional development they have found most useful (Computing At School, 2016). Here we see that teachers are accessing a range of forms of professional learning opportunities, including workshops given by universities and Master Teachers, which demonstrates that a learning curriculum should include varied opportunities to suit individual teachers needs. Other survey responses revealed that many teachers have carried out self-study subject knowledge development, with 70% of teachers reporting that they had spent more than 16 hours on this; some teachers in the survey reported that the only PL they had been involved in was self-study.

When asked to choose just one professional development activity that was most useful, 25% of teachers identified the sharing of good practice as most useful, with 20% specifying attendance at training events.

Teaching Computing includes teaching CS, IT and digital literacy. The CS elements of the curriculum are new to many Computing teachers so part of the survey in 2016 asked for teachers feelings about teaching the CS elements of the curriculum. Several statements were given for teachers to agree or disagree with. Between 775 and 778 teachers answered each question and the responses are shown in Table 3.

There is a strongly positive response to enjoyment of teaching Computing. 95% of teachers agreed or strongly agreed that they enjoyed teaching the CS elements of the Computing curriculum. At the same time, 69% of teachers agreed or strongly agreed that some of the concepts were difficult to teach. 90% of teachers agreed that they had gained confidence since the introduction of the curriculum (at the time of the survey in its second year) and as can be seen elsewhere in the survey, 87% agreed that they had to work hard on their subject knowledge. 13% of teachers said they did not know

where to find good quality resources for teaching, although the majority did (being a CAS members survey, there are resources both uploaded and signposted in CAS). 95% of the teachers said that their students enjoyed learning Computing.

In conclusion, a range of evaluation activities point to the effectiveness of the integrated approach to professional learning that has evolved through CAS.

## 5. Situated learning and PL in CS revisited

In this section we draw together the ways in which a situated learning perspective of Computing At School can enable it to move forward. We revisit our original question which was: *'How can professional learning for in-service teachers of Computing succeed?'*

One of the difficulties of effectively evaluating the CAS approach as a whole is that the effects are dispersed and distributed and so not necessarily easily traced back to the original PL activity (Boylan and Wills, 2014). However the evaluation activities that focus on the impact of particular ingredient activities within CAS paint a good picture, and in addition, ad hoc reports attest to more confident and empowered teachers working in Computing classrooms across England.

### *5.1. Communities of practice in CS teacher education*

CAS has evolved and new developments within it have been implemented incrementally, driven by teachers needs and supported by modest funding. The philosophy behind CAS's approach is to support teachers to become empowered and confident teachers in a new discipline. The basic premise is that good professional relationships between supportive peers underlie the best and most effective teacher PL. CAS is a learning community in which there are opportunities for teachers to learn from peers and more experienced others.

There are now many other countries where Computing has recently either been introduced, or been redesigned, in the school curriculum, for example Finland, Japan, Australia and South Korea, and parts of the USA. In all these contexts the key to successful integration lies with the teaching workforce, and the CAS model may be applicable elsewhere.

As professionals, teachers already work in CoPs in which they may feel more or less comfortable. Often the CoP is their teaching department but in some cases the department is a unit of one; in this case teachers are isolated and do not have a community within their school with whom to share practice. Wider CoPs include subject associations and groups that support teachers in a particular domain. The CoP gives an environment within which collaboration, networking and reflection can occur. The interplay between CoPs is one that teachers have to negotiate in accessing the support they need for their teaching. By viewing professional learning in Computing as a learning curriculum that teachers can access and subsequently practice in the classroom as they need to.

Another key element of this analysis is teachers need to interact with each other in order to move from LPP to a more central or full participation. More expert teachers who have been in an LPP position themselves can better understand a more novice teacher's interpretation.

*"Legitimate peripherality is important for developing 'constructively nave' perspectives or*

> *questions. From this point of view, inexperience is an asset to be exploited. It is of use, however, only in the context of participation, when supported by experienced practitioners who both understand its limitations and value its role."*(Lave and Wenger, 1991, p. 117)

To some extent everybody in the community is legitimately peripheral, according to Lave and Wenger, as the community changes. The CoP is not static and change can significantly affect the community.

### *5.2. Obstacles and difficulties*

The CAS community, and the provision of learning opportunities using the model described here, is not without its difficulties. During the evaluation of the learning curriculum, we have observed and experienced two main challenges: *time* and *scale*. Time refers to that needed for teachers to feel confident in the classroom and scale refers to the problem of reaching all teachers in England compared to the number currently accessing CAS opportunities.

Any investment into a teacher professional development programme needs to take account of the time teachers need to devote to developing their curriculum and pedagogical knowledge. This requires time for the teacher to work with CAS Master Teachers and time to focus on teacher research projects, work for certification, and develop new resources for teaching - all of which will have a positive impact on student learning. In part due to a lack of funding, there has been an expectation that teachers can utilise their unpaid time to participate in professional learning. Although teachers will gain participatory knowledge through practice in the classroom, engagement in the community needs focused time.

Lack of time means that the period of time teachers spend in LPP can be considerable. The implementation of the Computing curriculum in England was not planned with any indication of the time needed for transition and our experience is that this has caused many teachers to feel uncomfortable when it is not clear how long it will take them to be effective computing teachers. This obstacle seems more obvious when viewed from a situated learning perspective. Communities of practice do not evolve overnight and a teacher learning by participation needs time to embed new practices into the classroom.

Another issue is that the community requires goodwill and teachers to volunteer. This inhibits scale as in some case the changes to the CoP come about because the 'old-timers' no longer have the time to contribute to the community. More investment is needed to overcome this. At the time of writing the recommendations in the most recent Royal Society report include a call to government to provide more funding for professional learning (The Royal Society, 2017). The government have responded to this and so we await developments.

### *5.3. Top-down versus bottom-up activity*

Computing At School is a bottom-up, grass-roots working group and illustrates teacher professional learning from a situated learning perspective. Various activities form the learning curriculum that is part of the CoP. Each of these elements is important in the 'offer' to teachers although teachers will have differing needs.

As an organisation, CAS could be likened to the 'leaderless' organisations described in the book The Starfish and the Spider, which describes how an organisation that is not dependent on central governance can work so effectively: *" . . . for the starfish*

*to move, one of the arms must convince the other arms that it's a good idea to do so."*(Brafman and Beckstrom, 2006, p.37). As society evolves, we are increasingly situated in an era of grass-roots, bottom-up development. Top-down initiatives seem old-fashioned. As new businesses can be crowd-funded by communities of supporters (Ordanini, Miceli, Pizzetti, and Parasuraman, 2011), teachers are empowered by having autonomy over their own professional development.

In contrast, in terms of the curriculum in England, we have the top-down, policy-driven implementation of Computing as a mandatory subject for all children in state-governed schools. At the same time we have moved from detailed prescribed teaching frameworks to programmes of study that are summarised on one or two pages. These bring the need for local interpretation - difficult without solid experience of teaching computing over many years. At the same time education policy is moving towards a more school-led model, although schools are all new to the subject. Huge change of this nature cannot work without provision of funding to support teachers - there is a danger that a school-led approach does not receive the required funding needed to support the professional development of all teachers. Teachers need to be released from school to support teachers; and also teachers have to be released from school to meet other teachers and engage in the community activities described in this paper. Therefore the top-down funding provision needs to value bottom-up activity.

Community-driven activities act to implement an initiative set in motion at government level. The issue of scale outlined above has arisen because a gap has emerged between the top-down mandatory curriculum and the development of bottom-up solutions to support teachers. Funding is required to fill this gap and to ensure that teachers can access the professional learning that they need. To our knowledge, this aspect of developing teacher knowledge is not explained within situated learning theory.

To return to our original question, we assert that a CoP of Computing teachers provided with a learning curriculum that includes *"access to a wide range of ongoing activity, old-timers and other members of the community, and to information, resources, and opportunities for participation"*(Lave and Wenger, 1991, p.100) is the key to success in the training of teachers. But it will take time.

## 6. Conclusion

Computer science education research can be considered from a socio-cultural perspective (Kolikant, 2008; Machanick, 2007; Tenenberg and Knobelsdorf, 2014) which enables researchers to consider how learning is impacted by society, the environment and social factors, and does not purely view learning from an individualistic perspective. Situated learning explains learning in a social context and is particularly pertinent to teachers' professional learning. In Computing the advent of computing in school has brought the need for teacher PL to the fore and thus it is timely to consider how collaboration and community impact on a teacher's learning in Computing.

In considering a learning curriculum, pedagogy is as important as subject knowledge in Computing. Teachers are aligning their new knowledge to pedagogical practice. Subject knowledge, and its relationship with pedagogy, is complex and emerges in practice (Ellis, 2007). For example, in terms of teaching computer programming to students, teachers may have their own difficulties with writing programs, as well as being aware that students find the subject difficult and have misconceptions. Teachers may struggle to find strategies to support students, and may not be able to explore

concepts in depth (Yadav *et al.*, 2017). Sensitivity to the situation teachers are in should inform all professional development programmes.

In this paper we have described and analysed Computing At School from a situated learning perspective. This analysis gives a deeper insight into the impact of CAS in two ways. Firstly by analysing CAS in this way we can understand some of the ways in which the multiplicity of CoPs are changing as newcomers move from LPP to more central participation, bringing new ideas, although this multiplicity does make it difficult to sometimes distinguish participation from practice (Handley *et al.*, 2006). We can understand that old-timers in the CAS communities need to adjust to incorporate new practices. Secondly, this analysis helps us to understand that the transition to become a teacher of Computing takes some time - as knowledge has to become embedded as new practice in the school setting.

The contribution in this paper is to bring a theoretical perspective to play in the discussion of teacher PL in Computing, which we hope will have resonance in other contexts. An understanding of situated learning, including the gradual transition from LPP to increased participation and the evolution of CoPs over time, can help us facilitate interventions that enable more community-focused professional learning for computing teachers. CAS, and the curriculum in England, seemed to be unique a few years ago, but many other countries are now moving in the direction of a computing curriculum across all phases of education. We maintain that professional learning that is delivered, formulaic and didactic will not help teachers and learners, or a subsequent raising of standards in the classroom, as much as an understanding of the ways in which teachers support and learn from each other.

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