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Professional Recognition Matters: Certification for In-service Computer Science Teachers

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ABSTRACT

In the context of rapid curriculum change, teaching computer science in school requires new skills and knowledge that existing teachers may not have. As well as a programme of teacher professional development (TPD), certification can be used to provide recognition to in-service teachers who have made the transition to computer science. The BCS Certificate in Computer Science Teaching has been designed and developed to give teachers professional recognition of their competence in teaching the computer science elements of the Computing curriculum. In this paper we describe the innovative design of this national certification and our experience over the last two years of its implementation; we are not aware of any similar scheme to offer professional recognition to in-service K-12 computer science teachers.

Keywords

accreditation; certification; computer science curriculum;in-service teacher education; K-12 teachers; professional development;

1. INTRODUCTION

Many teachers in England are responding to changes in the Computing curriculum, now mandatory from age 5-16 in state funded schools. The new curriculum has some similarities with the previously taught ICT curriculum in terms of IT and digital literacy content but there is now a substantial focus on computer science.

Figure 1 shows some of the content that students aged 11-14 (Grades 6-8) need to cover, including algorithms, programming in two or more programming languages, boolean logic, binary numbers and hardware. Students aged 14-16 (Grades 7-9) who choose computer science need to understand about aspects of programming such as 1 and 2-dimensional arrays and file handling. In addition to understanding a range of algorithms and how to use programming to implement them, students also need to learn new theoretical content in the form of understanding networks, computer architecture, data representation and logic. In primary schools, the curriculum for children from ages 5-11 (Grades 1-5) includes computational thinking, algorithms, block-based programming and networks [10].

Teachers of Computing in England need to feel confident both in their content knowledge, and their pedagogical skills in teaching the content, in other words, their pedagogical content knowledge (PCK). There are now many courses and training options available for teachers to attend, primarily in their own time. But how can the knowledge required by a teacher be assessed? How can a teacher convince a head teacher that they are competent to teach the new subject? In this context we sought to design and implement a new certification scheme for teachers of computer science (CS) to complement other aspects of TPD.

The BCS[1] Certificate in Computer Science Teaching (see Figure 2) is an evidence-based certification scheme— from now on referred to as 'the Certificate'—for teachers currently teaching Computing. It consists of three parts. The first part involves demonstrating engagement with professional development (PD) opportunities, reflecting on and implementing new skills and knowledge. The second part involves the demonstration of technical competence and involves creating a program of the teacher's choice that is useful in a teaching context. The third part involves reflecting on pedagogy via a small classroom investigation examining a particular approach to delivering the Computing curriculum.

In this paper, we describe the need for certification for CS teachers, the design of the Certificate and our experience of its implementation.

2. SUPPORT FOR CS TEACHERS

Professional development is an essential part of improving school performance and learner outcomes [6]. Teachers often participate in many hours of training or other prescribed TPD in school or college and attend many external courses in order to improve their own skills in teaching and learning but sometimes even the most well-intentioned efforts to change do not succeed [2]. Evidence points to the fact that teacher professional development should be sustained over time and connected to practice [9, 29, 30]. For sustained change, a framework should be provided enabling teachers to access professional development opportunities, whilst retaining the energy that comes from teachers work-

[1]BCS, The Chartered Institute for IT (http://bcs.org) is a subject association for IT providing standards, frameworks and qualifications for industry and accreditation for university degrees

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Figure 1: Curriculum content at Grades 6-8 [10]

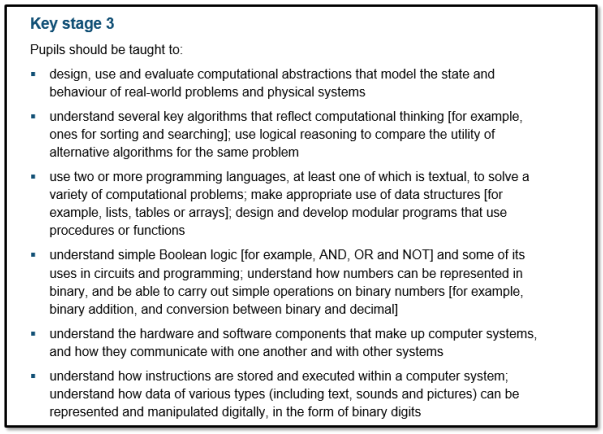
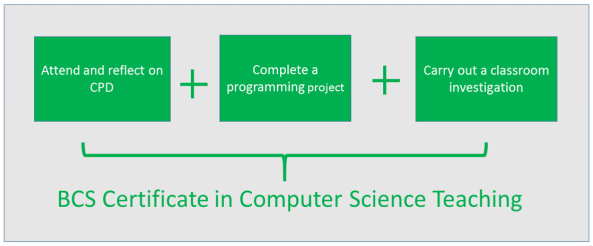


Figure 2: The BCS Certificate in Computer Science Teaching



ing together informally to feed their own TPD needs.

A comprehensive survey of pre-service computer science teacher education by Armoni [1] describes the need for well-informed educational professionals with an understanding of both content and pedagogy. To improve the supply of new computer science teachers, increasingly pre-service teacher education courses are being developed or refined [31, 7, 12]. Certification within initial teacher education gives new teachers a thorough grounding in pedagogical knowledge, PCK, and also curricular knowledge [12]. However, certification within in-service computer science teacher education is not often discussed, with a few exceptions [15, 11].

In terms of TPD in CS more generally, much of the support for developing Computing teachers is via training courses and workshops, which suggests an emphasis on a deficit model [16]. However, Kolikant and Pollack highlight the importance of interactions between teachers in in-service professional development in CS [18] and implementations have reported notable success [28, 13, 25, 22]. In a more multi-faceted approach to TPD for K-12 teachers [23, 25], a range of TPD opportunities can be made available, and certification can complement these.

3. THE CONTEXT

The context in which this certification has been implemented is one of curriculum change across England, affecting teachers in both primary and secondary phases. A new subject, Computing, which comprises some elements of the previous subject, ICT, but with a considerable amount of new academic (i.e. not based on technology alone) material, has been introduced into the curriculum [8]. Moreover this incorporates fundamental concepts of computer science with which some teachers are unfamiliar, and others rather rusty. Recent reports have identified that only 44% of Computing teachers hold a post-school qualification in the subject [20] and that there are currently an estimated 14,000 [secondary] teachers delivering ICT who will need support and training to teach computer science [4].

There are several initiatives in England to support teachers in the transition from teaching ICT to teaching Computing, including those emanating from Computing At School (CAS). CAS is a grass-roots organisation in the UK which has had a great influence on the emerging changes. CAS exists to provide leadership and strategic guidance to all those involved in Computing education in schools in the UK [24]. Several initiatives within CAS support TPD, including the Network of Excellence, CAS Master Teachers, and the Barefoot, Tenderfoot and Quickstart resources. Computing Massive Open Online Courses (MOOCs) have also been developed and deployed to support teachers develop computer science subject knowledge and pedagogy [26].

4. DESIGN CONSIDERATIONS

The Certificate is a CAS initiative and accredited by BCS. It was designed and implemented by the first author to complement other CAS activities. In this section we outline the rationale for its design.

4.1 Criteria

The design of the certification drew on research from both teacher professional development and experiential learning. The certification had to meet the following criteria:

- It had to be relevant to teachers with a wide range of existing knowledge and skills. This is in contrast, for example, a university undergraduate or pre-service teacher programme where it can be assumed that students start at roughly the same place.
- It had to be achievable by busy teachers who were in the classroom full-time, by involving activities that would be directly useful to them as teachers.
- It should be rigorous enough to ensure that certified teachers were confident enough in their programming skills to be able to assist students in project work.
- The certification should be centred around a supportive and empowering community of practice.

4.2 Learning by experience

Experiential learning describes the process of engaging learners in an authentic experience in which they can make discoveries and experiment with knowledge at first hand. As well as learning by actually practising the skill, experimentation and reflection are also key [17]. A proponent of experiential learning, Mark Smith, proposes that people learn in the following three ways:

- people learn best when they are personally involved in the learning experience;
- knowledge has to be discovered by the individual if it is to have any significant meaning to them or make a difference in their behaviour; and
- a person's commitment to learning is highest when they are free to set their own learning objectives and are able to actively pursue them within a given framework. [27, p.14]

In CS, Liberman et al [19] demonstrate that teachers can behave like novices and experts at the same time – and propose that teachers' developing PCK will help them master new and difficult CS concepts and that their own learning experiences help them to support students.

In addition, our own experience of running professional development courses in programming had led us to realise that attending courses alone did not give teachers confidence in their ability to design and develop complete working programs. The confidence to be able to support students working on their own projects comes from working with whole programs rather than short snippets of code. Thus, the importance of learning by experience was key in the design of the Certificate.

4.3 Formative assessment

Certification is necessarily implemented by summative assessment. Long-standing and well-respected research points also to the value of formative assessment in enabling the learner to progress his or her understanding from the feedback given, which should be constructive and developmental [3]. Formative assessment also helps students to appreciate the standards that are expected from them [32], and, although it can be criterion-referenced, it should be positive in intent and developmental for the learner [14]. It was important to incorporate both formative and summative assessment in the design of the certification. Thus the design of the Certificate included regular opportunities for feedback from supportive assessors, and focused on reflection on learning.

4.4 Integration within a broader framework

The Certificate was not designed to be a stand-alone offering to the teaching community. It is part of an integrated model of TPD that can be used to frame CAS activities [25] (see Figure 3). The focus of CAS has always been around face-to-face training, networking and mentoring [24] with the development of the Master Teacher programme [25]. Teachers can use the training and support provided by CAS Master Teachers or undertaken elsewhere to develop evidence towards the Certificate.

The integrated model of TPD consists of the following six elements, centred on a community of practice:

- Community of Practice
- Training
- Mentoring and coaching
- Cascade
- Classroom-based research
- Certification

Certification is an important aspect of this framework because it can be linked to other developmental initiatives to support teachers and provides a goal. The certification is separated from training and other elements of the model, so that PD opportunities can be selected that are appropriate to an individual teachers' need.

5. IMPLEMENTATION

The BCS Certificate in Computer Science Teaching was launched in October 2014, after a six month pilot. The pilot phase enabled us to establish clear assessment criteria, time frames and teacher guidance for the Certificate. 25 teachers completed the pilot.

Figure 3: An integrated model of TPD

The Certificate comprises three parts. Teachers need to provide evidence for all three to gain the Certificate and parts can be completed in any order. There are two versions of the Certificate for primary and second teachers, differing in terms of the assessment criteria for the programming project (Part 2).

5.1 Part 1: Reflection on the journey

Part 1 of the Certificate is awarded when teachers have adequately reflected on their experiences of at least 20 hours of eligible CS PD. Eligible PD is that which has been undertaken within two years of the time of submission for the certificate, and includes any training, networking meeting, subject-based conference or MOOC which can be shown to have supported a teacher's professional development. At least half must be made up of face-to-face professional development.

This structure enables teachers to select the subject knowledge training that most meets their individual needs. Teachers should reflect on the benefit to them of the course or training, and on the impact on their learners. They should be able to describe where they are in their journey and what they still may need to learn going forward.

5.2 Part 2: Programming skills

The second part of the Certificate requires teachers to develop a project of their choice. Project-based learning is well-known as an approach to develop motivation and understanding [5] and programming skills need lots of practice to develop.

The project must evidence certain minimum skills and should be a working and useful piece of software or tool. The function of the program is important as teachers should aim to inspire their students with the relevance of computer science to everyday life, but often classroom examples are not useful pieces of software: this project should be a working program that teachers will actually use. Following the Certificate's 'rigorous but not onerous' strap-line, only minimum amounts of documentation are needed.

As an example, a program developed by a secondary teacher was a computer science knowledge quiz developed in Python. This program reads in questions from a file, randomly generates questions, returns a score, writes the user name and score to a score file, generates a traffic light level based on the score achieved and displays a personalized certificate.

5.3 Part 3: Focus on pedagogy

Reflecting on the effectiveness of different approaches to teaching their subject is a key part of any teacher's PD. This is essential in Computing as the computer science elements

are new to the curriculum. We have a growing understanding of good pedagogical approaches for teaching CS and thus a focus on PCK is important.

For Part 3, teachers investigate an aspect of computer science pedagogy, by choosing a particular approach to use, carrying out a small intervention, and then evaluating its success. The classroom investigation is not extensive but it serves as an introduction to classroom research in Computing, and benefits teachers in developing insights into their pedagogy [21]. An example of a Part 3 project might be a small scale classroom investigation into teaching binary to secondary students using Computing 'unplugged-style' activities in the classroom.

5.4 Assessment

The Certificate is built round a framework of formative assessment and e-assessors will repeatedly give feedback to assist the teacher and enable them to adequately reach the standard. E-assessors are primarily academics in the field of computer science education or computer science, and have considerable expertise to share with the teachers when considering their work. For example, a teacher may submit a programming project that they feel is ready for assessment as a draft; the e-assessor suggests ways in which the code may be made more efficient, for example by using functions with parameters. Because the feedback is given to the teacher about a program that they have developed themselves, and over which they have ownership, the suggestions for modification to the program may make more sense to them than just working through an exercise on passing parameters into functions.

Once recruited, e-assessors are inducted into the mechanics of how the Certificate operates, the process of providing formative assessment to a teacher and they complete a standardization activity to ensure that the rigor and robustness of the Certificate is maintained. A community of practice has been established for the e-assessors with them meeting physically or virtually three times a year, with the Certificate team and the Senior Assessor, to disseminate good practice, participate in standardization activities, and discuss and suggest developments with the Certificate.

6. EXPERIENCE TO DATE

6.1 Recruitment

The Certificate has been running for 2 years and over 400 teachers have enrolled (see Table 1). Teachers are primarily from England, with a small number from elsewhere in, or outside of, the UK.

Each teacher has up to one year to complete their evidence, but this time includes submitting drafts and acting on feedback given by e-assessors. Teachers vary widely in how long it takes them to pass the Certificate, depending on their starting point and time available to work towards it. Some teachers can complete it in a few months, whereas others need the full year.

6.2 Teacher feedback

A short survey was designed to review teachers' feedback on their experiences on completion of the Certificate. To date, 36 teachers (37%) have responded to the invite to provide feedback on and influence the future direction of the Certificate with 33 giving permission for research purposes.

Table 1: Recruitment and Completion rates

Recruitment			
Period	Primary	Secondary	Total
09/14 - 02/15	17	100	117
03/15 - 08/15	20	48	68
09/15 - 02/16	17	65	82
03/16 - 08/16	32	135	167
Total	**94**	**387**	**473**
Completion rates			
03/15 - 08/15	4	12	16
09/15 - 02/16	6	26	32
03/16 - 08/16	20	28	48
Total	**30**	**66**	**96**

Teachers were asked the following five open-ended questions:

1. Why did you decide to enrol for the BCS Certificate in CST?
2. How did you manage to fit your working towards the Certificate around your full time teaching position?
3. In what way was having an e-assessor helpful (or not helpful)?
4. Do you think undertaking the Certificate is an important part of on-going professional development for teachers?
5. What do you think you have learned having completed the Certificate?

Answers to the questions have been classified by the authors to identify themes in responses. In response to question 1, some teachers gave more than one reason for taking the Certificate. For example, one teacher said:

> "To update my knowledge on Computer Science to prepare myself for the changing curriculum in schools and gain an accredited certification."

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More than half the teachers (51%) wanted to achieve a professional recognised qualification. Another reported that:

> "I did not study computer science at university. Over the last few years I have developed my subject knowledge through self study and attending a range of courses. I felt the certificate would give me some recognition of my efforts and to give perspective employers confidence in my ability to teach the subject."

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More than half wanted to develop or enhance their subject knowledge. 27% (n=9) mentioned that they wanted to enhance their computer science pedagogy, 15.2% (n = 5) their self-efficacy, 9% (n = 3) develop competence in programming, 6.1% (n = 2) respond to curriculum changes and one teacher was recommended to undertake the Certificate by his manager.

In response to the second question respondents offered the following strategies that they had adopted: accessing their assessor, using provided resources, time management, working evenings and weekends, working holidays, utilising

a support network and applying for extensions. The intention of the Certificate design, although not achieved by all teachers, is that they can fit tasks around their teaching year, as here:

> "Blended tasks with actual teaching - used program from task 2 to train staff and students. Used class activity to develop task 3."

Challenges teachers reported that they encountered in completing the Certificate included balancing working full-time and studying part-time, managing time constraints, and embedding classroom investigation.

Teachers' responses to question 3 were primarily positive with some negative responses. Twenty nine teachers (88%) praised the supportive nature of their assessors with regarding to timely constructive feedback and further guidance:

> "My e-assessor very helpful in giving the feedback and ideas to make sure I completed all the tasks given."

In response to the fourth question "Do you think undertaking the Certificate is an important part of on-going professional development for teachers?", 97% of respondents (n = 32) gave a positive response. One teacher stated that:

> "I definitely believe that the switch of focus away from ICT to Computing needs addressing, and the certificate is a clear way to evidence teachers taking responsibility for their own CPD and that they have reached a good standard of Computing knowledge."

In the final question what had been learned by completing the Certificate, responses included new subject knowledge, new programming techniques, how to use a Graphical User Interface (GUI), unplugged activities, pseudocode and flowcharts and reflecting on professional practice in Part 3. One teacher concluded:

> "There were many moments when I thought that I would be unable to complete certain required tasks. Completing the certificate has given me the confidence I needed, in my ability as a teacher, to move forward in this field. I have left the certificate with a clear understanding of the requirements for teaching and the necessity of learning. I will be continuing with my CPD in computer science for some time to come."

Less positive feedback was around the importance of timely e-assessor feedback and interaction, and two respondents (6%) indicated that the cost of the Certificate could be a potential barrier if teachers were to pay for it themselves.

6.3 Modifications over time

The Certificate was established by a very small team; it is now being absorbed into larger organisational systems. Over the last two years, several modifications have been made to address limitations and feedback from teachers.

- **The Guided Route**: The Certificate now has two routes: the Guided Route and the Independent Route. The Guided route includes online synchronous evening courses with a maximum of 15 teachers so that the tutor can give appropriate support and feedback. This has been a popular route and has attracted over 100 teachers. The Guided route takes the teachers to the proposal stage of the Independent Route.
- **E-assessor monitoring**: Early teething problems with e-assessors alerted us to the fact that careful monitoring is necessary, along with quality assurance of feedback given; systems are now in place for this.
- **Start dates**: Originally a teacher could start at any time to provide maximum flexibility to teachers. Administratively this proved to be inefficient; teachers now enrol on the Certificate at bi-monthly intervals.

The Certificate is continually evolving and developing, and there is increasing interest from outside the UK.

7. CONCLUSION

For a large teaching workforce at different stages of the journey to being competent and confident Computing teachers, a more easily accessible recognition of teachers' competence is needed, without necessarily involving an academic course at a university. In this paper we have described the design and implementation of a unique and innovative certification scheme for in-service Computing teachers that forms part of a holistic model of professional development. The Certificate is continually evolving, and complements a growing range of training opportunities so that teachers can choose what professional development they need for their teaching. The key features that characterise this certification are that a teacher's route to achieving it is personalised, it involves formative assessment, and it involves teachers working on pedagogical investigations and programming projects that relate to their own teaching experience. Feedback from teachers who have completed the Certificate to date is positive.

There are obviously some barriers to adoption. Despite attempts to make the cost minimal, some headteachers are not willing to pay for teachers to take the Certificate, other teachers feel that they don't need the Certificate because they already have the skills they need, and others are unaware of its existence. Some teachers on the Certificate who are working at the same school 'buddy up' to work together: this is very beneficial and the introduction of the Certificate to all teachers at a school at one time might counter some of the obstacles faced.

Overall, we are proposing that there is the potential for this national certificate to be a de facto standard for teachers of Computing. The innovative approach taken here may therefore be of interest to other countries wishing to support in-service teachers in a similar way.

8. ACKNOWLEDGMENTS

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9. REFERENCES

[1] M. Armoni. Looking at secondary teacher preparation through the lens of computer science. *Trans.Comput.Educ.*, 11(4):231–2338, Nov. 2011.

[2] B. Bell and J. Gilbert. *Teacher development: a model from science education.* Falmer Press, London, 1996.

[3] P. Black and D. Wiliam. *Inside the black box: Raising standards through classroom assessment*. Granada Learning, 2006.

[4] N. Blackwood. Digital skills crisis: second report of Session 2016–17. *House of Commons Science and Technology Committee Report*, 2016.

[5] P. C. Blumenfeld, E. Soloway, R. W. Marx, J. S. Krajcik, M. Guzdial, and A. Palincsar. Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, 26(3-4):369–398, 1991.

[6] R. Bolam. Emerging policy trends: some implications for continuing professional development. *Journal of In-Service Education*, 26(2):267–280, June 2000.

[7] I.-C. Borza. New methods for learning in computer science education. In *Balkan Region Conference on Engineering and Business Education*, volume 1, pages 629–632, 2014.

[8] N. Brown, S. Sentance, T. Crick, and S. Humphreys. Restart: The Resurgence of Computer Science in UK Schools. *ACM Transactions of Computing Education*, 14(2), June 2014.

[9] CUREE. Understanding what enables high-quality professional learning. Technical report, 2013.

[10] Department for Education. National Curriculum for England: Computing programme of study. Technical report, Department for Education, London, England, 2013.

[11] C. L. Fadjo, T. Brown, and L. A. DeLyser. A Curriculum Model for Preparing K-12 Computer Science Teachers. In *Proceedings of the International Conference on Frontiers in Education: Computer Science and Computer Engineering (FECS)*, 2013.

[12] J. Gal-Ezer and E. Zur. What (else) should CS educators know?: revisited. pages 83–86. ACM, 2013.

[13] J. Goode. If you build teachers, will students come? the role of teachers in broadening computer science learning for urban youth. *Journal of Educational Computing Research*, 36(1):65–88, 2007.

[14] W. Harlen and M. James. Assessment and Learning: differences and relationships between formative and summative assessment. *Assessment in Education: Principles, Policy & Practice*, 4(3):365–379, Nov. 1997.

[15] A. Jackson. In-service education for teachers of computer science. *ACM SIGCSE Bulletin*, 8(1):29–34, 1976.

[16] A. Kennedy. Understanding continuing professional development: the need for theory to impact on policy and practice. *Professional Development in Education*, 40(5):688–697, Oct. 2014.

[17] D. Kolb. Experiential learning as the science of learning and development. *Englewood Cliffs NPH*, 1984.

[18] Y. B.-D. Kolikant and S. Pollack. Community-oriented pedagogy for in-service cs teacher training. *SIGCSE Bull.*, 36(3), June 2004.

[19] N. Liberman, Y. B.-D. Kolikant, and C. Beeri. "regressed experts" as a new state in teachers' professional development: lessons from computer science teachers' adjustments to substantial changes in the curriculum. *Computer Science Education*, 22(3):257–283, 2012.

[20] National Audit Office. Training new teachers. Technical Report HC 798, Feb 2016.

[21] G. Pine. *Teacher Action Research*. Sage Publications, 2009.

[22] J. Ryoo, J. Goode, and J. Margolis. It takes a village: supporting inquiry-and equity-oriented computer science pedagogy through a professional learning community. *Computer Science Education*, 25(4):351–370, 2015.

[23] S. Sentance, M. Dorling, and A. McNicol. Computer science in secondary schools in the UK: Ways to empower teachers. In *International Conference on Informatics in Schools: Situation, Evolution, and Perspectives*, pages 15–30. Springer, 2013.

[24] S. Sentance and S. Humphreys. Online vs face-to-face engagement of computing teachers for their professional development needs. In *International Conference on Informatics in Schools: Situation, Evolution, and Perspectives*, pages 69–81. Springer, 2015.

[25] S. Sentance, S. Humphreys, and M. Dorling. The Network of Teaching Excellence in Computer Science and Master Teachers. In *Proceedings of the 9th Workshop in Primary and Secondary Computing Education*, pages 80–88. ACM, ACM, 2014.

[26] J. Sinclair, R. Boyatt, J. Foss, and C. Rocks. A tale of two modes: initial reflections on an innovative mooc. In *International Workshop on Learning Technology for Education in Cloud*, pages 49–60. Springer, 2014.

[27] M. Smith. *Creators not consumers: rediscovering social education*. NAYC Publications, 1982.

[28] D. Thompson and T. Bell. Adoption of new Computer Science High School Standards by New Zealand teachers. In *Proc. of 44th SIGCSE technical symposium on Computer science education*, SIGCSE '13. ACM, 2013.

[29] J. H. Van Driel, D. Beijaard, and N. Verloop. Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of research in science teaching*, 38(2):137–158, 2001.

[30] R. C. Wei, L. Darling-Hammond, A. Andree, N. Richardson, and S. Orphanos. Professional Learning in the Learning Profession: A Status Report on Teacher Development in the US and Abroad. Technical Report. *National Staff Development Council*, 2009.

[31] C. Whitehead, L. Ray, S. Khan, W. Summers, and R. Obando. Implementing a computer science endorsement program for secondary school teachers. In *Proceedings of the 42Nd ACM Technical Symposium on Computer Science Education*, SIGCSE '11, pages 547–552, New York, NY, USA, 2011. ACM.

[32] M. Yorke. Formative assessment in higher education: Moves towards theory and the enhancement of pedagogic practice. *Higher education*, 45(4):477–501, 2003.