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Chapter 1

Introduction

We don't know how CS teachers teach

Despite the demand for high quality educators in Computer Science almost nothing is known about how our teacher's teach programming. The teaching strategies and practices that CS teachers use are not empirically reviewed. Because of this, the knowledge that Computer Science teachers use in order to teach CS concepts remains unclear. For example, Pears et. al's (2007) literature review on introductory programming instruction failed to provide an answer on how to teach introductory CS due to the scarcity of systematic evidence that may support any answer (Pears et al., 2007). This is not surprising due to the fact that Computer Science Education is young compared to other scientific fields like Physics, Biology and Chemistry. Because Computer Science Education is a relatively young field, there is no benchmark on how good CS teachers teach Computer Science or how effective current practices are.

Measuring PCK is difficult

One of the trending fields in in science education research right now is about teacher knowledge. One of the domains of teacher knowledge is the construct of teacher's pedagogical content knowledge (PCK). PCK is a construct introduced by the Social Science researcher Lee Shulman in the 1890's (need exact). Although this construct has been around for decades, the most recent breakthroughs on this field are about PCK's theoretical roots and PCK's conceptualizations. (Park & Oliver, 2008) Many researchers have discussed the complexity of PCK (Rohaan, Taconis, & Jochems, 2009,Yadav, Berges, Sands, & Good (2016)) and because of this, there is yet to be a widely used measurement tool for it. Measuring a teacher's PCK directly is difficult, it is challenging to document such a broad and abstract concept. This is bigger problem on young research fields like Computer Science Education. Because of all of this, Computer Science Education research falls behind other fields in terms of an understanding of teacher's PCK (Yadav et al., 2016).

PCK is an empirical evidence for good teaching practices

Currently there are no widely accepted standards of teaching in Computer Science Education (Rohaan et al., 2009). This affects Computer Science teachers' personal standards of teaching. When CS teachers' decide to switch between preferred teaching techniques and practices they base their choice on anecdotal evidences, informal judgement, and intuition (Fossati & Guzdial, 2011). Measuring PCK for introductory CS teachers will allow us to compare teaching practices using empirical evidence. This is important because, empirical evidence is needed so that the community can use research to answer questions on how to teach programming (Pears et al., 2007).

PCK measures identify difficult to teach topics

Measuring mean PCK of teachers for each topic will give us insights on which topics are harder to teach. Topics in which teachers generally have lower levels of PCK can help identify topics in which teachers have trouble teaching. By combining knowledge of hard to teach topics to our existing knowledge of topics CS students have trouble learning (Goldman et al., 2008) we can verify if these two sets of topics are similar to each other. Knowing this will provide evidence to the hypothesis that poor performances of CS students are caused by poor teaching practices of CS teachers.

Good measures develop good teachers

There is demand for high quality CS teachers in the world right now. This makes the need for effective teacher training imminent. To create frameworks of improvement - focused teacher evaluation system, measurements for effective teaching is needed (MET Project, 2013). Multiple measures are needed in order to measure the multiple facets of science education. And from this measures we can build a good teacher evaluation system that can be the basis on how we train our teachers. Data from these measurements will show which teaching practices should be improved, changed or invested on (MET Project, 2013). Therefore PCK measurement tools will contribute knowledge on good standards of CS teaching which will be useful for CS teacher training.

Chapter 2

Related Work

Theoretical Perspectives

PCK as a knowledge base is a blend of pedagogy and content

Shulman (1987) described PCK as “the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction” (1986). It is one of the 7 knowledge bases a teacher draws from when reaching. PCK is separate from but related to a teacher’s pedagogy as well as a teacher’s content knowledge. For example an introductory computer science teacher with pedagogy and content knowledge only draws from his/her general pedagogical techniques to teach recursive statements. This teacher knows the concept of recursion and this teacher also knows how to speak in public and knows how to make tests. On the other hand a teacher with a developed pedagogical content knowledge knows how to specifically teach recursion. This teacher knows the common questions students have about recursion, knows which questions to ask to effectively test students’ knowledge in recursion and knows students’ misconceptions about recursion.

Students develop a teachers PCK

Shulman (1987) has suggested that the development of a teacher’s PCK is affected by the students that the teachers teach (1987). According to Shulman (1987), students affect teachers’ PCK through formal and informal assessments but a more recent study has shown that there are more direct means that students impact a teacher’s PCK (Park & Oliver, 2008 ; 1987).

One way students affect the development of PCK is through challenging questions that facilitate subject matter knowledge (Park & Oliver, 2008). Although subject matter knowledge is a separate knowledge base from PCK it has been considered one of the criterions for PCK development (Driel, Verloop, & Vos, 1998). The teachers studied by Park and Oliver (2008) often encountered students questions which challenge their subject matter knowledge. These encounters changed the teachers subject matter knowledge so that it could be used to teach students successfully (2008).

A second means of student impact on the development of PCK is through the assessment of student participation and responses during class. Student participation and response is manifested from "students' enjoyment, evidence of learning, and other nonverbal reactions to instructional strategies". Based on these informal responses teachers instructional strategies are replaced, modified or validated (Fossati & Guzdial, 2011; Park & Oliver, 2008).

The third means of PCK development from teacher responses is from assessing students' creative and critical ideas. This simply means that that students critical inputs and ideas during class are used by the teacher to look for innovative and interesting strategies of teaching (Park & Oliver, 2008).

Knowledge of students' misconceptions is a sign of a developed PCK

Student misconceptions about the topic also shape the teacher's PCK. Knowledge on student misconceptions is transformed into the knowledge of techniques on how to teach the topic that addresses the misconception or avoids the formation of the misconception (Park & Oliver, 2008). Park and Oliver's (2008) findings show that teachers understanding of their students' misconceptions shaped the entire teaching process "from planning to assessment" (2008). Their interviews with teachers show that expanding teacher's knowledge of student misconception ultimately improved their PCK. From this, Park and Oliver (2008) concluded that "as teachers developed better understanding of students' misconceptions, their PCK became more sophisticated" (2008).

This supports Shulman's (1986) early incarnations of the PCK construct (1986). Shulman (1986) included knowledge of student misconceptions as one of the components of PCK. According to him, student preconceptions, which are often misconceptions, require teaching strategies that reorganize these into correct conceptions (Shulman, 1986). Even non-PCK related teaching studies have suggested that teachers' knowledge of student misconceptions is crucial for effective teaching (Ausubel, 1968). Some researchers even stress that KOSM is a required knowledge base for teachers who teach the topics (Carlsen, 1999).

Misconceptions relate PCK to Conceptual Change Theory

One of the emerging conceptual change theory perspectives is the idea of theory change. It states that learners' conceptual frameworks are embedded intuitively and that it is different from that of an expert's conceptual framework. Therefore, these learners' conceptual frameworks require substantial restructuring to resemble the conceptual framework of an expert (Carey, 1985).

Learner's conceptual frameworks are comparable to the preconceptions of a student before a course. These preconceptions are often misconceptions that require restructuring in the form of science education (Shulman, 1986). Therefore, teachers equipped with the knowledge of these misconceptions become more effective catalysts of theory change. These teachers become better at shaping learners' conceptual frameworks (misconceptions) into experts' conceptual frameworks (correct conceptions). It could be argued that the motivation for teaching learners is not the process of filling up a learners blank slate but the process of changing the wrong contents of the learners' slate into correct contents (Sadler, Gerhard, Coyle, & Nancy, 2013). Recent papers on Conceptual Change theory suggest that this theory provides a bridging gap in researches of student errors and instructional practice. Duit and Treagust (2003) discuss the possible use of conceptual change process to examine scientific literacy to provide a framework for science education and teaching (2003).

State of the Art

Measuring PCK qualitatively

Loughran et. al's (2001) early works in representing PCK was through Pedagogical and Professional - experience Repertoirs (PaP-eRs) (Loughran, Berry, & Mulhall, 2012; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001). This method involves documenting on paper teacher's practices, anecdotes and insights on a topic. Although teachers PaP-eRs of a topic is not a complete representation of PCK it is a useful tool for sharing PCK in practice. Loughran et. al (200?) later expanded the documentation of PCK by adding the tool Context Representations (CoRe) which details their overview of concepts related to the topic (Loughran et al., 2012).

Based on Loughran et. al's (2012) CoRe's deBeer's (2009) study compiled a list of Big Ideas specifically for introductory computer science education (2009; 2012). The Big Ideas were produced using semi-structured group discussions of computer science teachers. Each of these Big Ideas have corresponding questions that assess a teachers' content knowledge, teaching strategies, and other pedagogical insights in said topic.

One of the most recent studies also use open ended questions for measuring PCK (Yadav et al., 2016). Yadav et al. (2016) used open-ended questionnaires that present common Computer Science situations that teachers may encounter. Although this test doesn't yield quantitative data, the teacher's responses generate rich qualitative data sets.

Measuring PCK quantitatively

Some studies used multiple choice approaches for easily quantifiable measurements of PCK. Although not exactly for PCK, one of the earliest test questionnaires to measure PCK was from Kromney and Renfrow's C-P items (1991). This study built multiple choice questions to measure content-specific pedagogical knowledge (Kromrey & Renfrow, 1991). Rohaan et. al. (2009) a constructed multiple choice questionnaire called the Teaching of Technology Test for primary technology education teachers (2009). Instead of using empirical data, the study used expert judgments to examine the contents validity.

KOSM and student learning

New studies on quantitative PCK measurements have focused on teacher's understanding of student misconceptions. Juttner and Neuhaus (2010) created PCK questions based on empirically analysed student errors to be used for a PCK test for biology teachers (Jüttner & Neuhaus, 2010).
The process for creating these test questions start with the gathering of the most common student misconceptions using a multiple-choice test for students. Questions for teachers are then created based on the common misconceptions gathered.

A similar process is also used by researchers from other fields. A study on the influence of teacher knowledge on middle school classrooms show that the teachers who could identify popular misconceptions had much larger classroom gains compared to teachers who only knew the answer (Sadler et al., 2013). In addition to that, this research concluded that a multiple choice assessment instrument could be used to assess the SMK (subject matter knowledge) and KOSM (knowledge on student misconception) of teachers. While Sadler's study doesn't explicitly discuss the concept of PCK itself, several conceptual studies discussed above show that the KOSM of students that Sadler identified are manifestations of PCK (Park & Oliver, 2008 ; Shulman, 1986). This study, like Juttner and Neuhaus' (2010) study constructed test questions and answers which are grounded by empirical evidence. Although, Juttner and Neuhaus' (2009) study unlike Sadler et. al's (2013) study, focuses on the source of student misconceptions more than the validity of the constructed PCK test (Jüttner & Neuhaus, 2010; Sadler et al., 2013).

On the field of Computer Science Education, some studies are also starting to consider misconceptions in PCK. Ohrndorf and Schubert (2013) created some test items to be used to assess student teacher's PCK. The test items created in this study are based on three measurable aspects of PCK: PCK test, PCK student, and PCK instruction. PCK student test items are questions on student's misconceptions and PCK instructions are questions on how to create instructions for solving misconceptions (Ohrndorf & Schubert, 2013). One of main differences of Ohrndorf and Schubert's (2013) study to Sadler et. al's study and Juttner and Neuhaus' (2010) study is that the formermost study created a test which yields qualitative data.

Gaps in Knowledge

Our current PCK tools are hard to build

Most PCK representation and measurement techniques involve verbalizing teaching practices or observing classroom management by teachers which easily highlight PCK in action (Beer, 2009; Loughran et al., 2012, 2001; Ohrndorf & Schubert, 2013; Rohaan et al., 2009; Yadav et al., 2016). But the problem is that these methods yield data which are too abstract or too difficult to quantitatively measure. Teachers may have difficulties in converting their own techniques into words introducing more variables and more complications in gathering the data. Also, current measurement tools (both qualitative and quantitative) are complicated to create from scratch. These tools and tests are derived from meetings and discussions by teachers or experts in the field (Beer, 2009; Loughran et al., 2012, 2001; Rohaan et al., 2009; Yadav et al., 2016) which require more planning than other knowledge bases like content knowledge (Kromrey & Renfrow, 1991). This is especially difficult since teacher's PCK is unique for each content. It will be very expensive and time consuming if we were to attempt building PCK tests for multiple topics using these methods.

PCK specific to CS education

Currently there are studies that show that effective middle school teachers are aware of the common misconceptions on the field they are teaching (Sadler et al., 2013) but there are no studies in CS right now that demonstrate this correlation. It has been shown that a multiple-choice questionnaire for students can be used as a KOSM (knowledge on student misconceptions) test for teachers. This was performed on middle school classes. Whether or not this is true on CS1 classes is not known as of the moment.

The set of topics which are difficult to teach

While there are studies that show which concepts CS students are having a difficulty on learning, there are no studies that identify which concepts CS teachers have difficulty in teaching (Goldman et al., 2008). Measuring the mean PCK of teachers around the world for each topic will reveal the topics that teachers have low PCK on. (help bad sentence) These topics will reveal insights on hard to teach concepts. This set of topics is important to find since the intersection between the set of hard to teach topics and the set of hard to learn topics will be provide evidence that CS students cant learn because CS teachers cant teach.

Chapter 3

Research questions

Because of these gaps in knowledge we aim to answer these questions:

- **Can the SCS1 test be repurposed into a PCK test?**

It has been shown in a previous study that a validated multiple choice tests for middle school students can be used to calculate teacher's knowledge on student misconceptions (Sadler et al., 2013). The SCS1 is proven to be a usable PCK tool if we find positive correlation between student gains and PCK tool test.

- **How does CS teachers' PCK relate to students' learning?**

Using the tool derived from SCS1 we will be able to measure the relationship between CS teachers PCK and student learning gains. The same tool can also be used to measure the following PCK related knowledge bases.

- How does CS teachers' content knowledge score relate to students' learning?
- How does CS teachers' ability to identify misconceptions relate to students' learning?

These specific research questions are asked so that we can measure how these knowledge bases relate to each other and also which of them matter the most.

- **Which introductory programming concepts are hard to teach?**

The tool can be used to measure the average PCK of teachers for each item in the repurposed SCS1 test. Test items in which teachers generally score low PCK can provide insight on which introductory computer science topics are hard to teach.

Chapter 4

Methodology

Research Method

It is much harder to measure each aspect of teacher competency to control the independent variable. Therefore the study cannot measure causal relationships. Also it is unethical to deliberately subject the students to incompetent teachers. According to Cohen et. al. (2007) the type of research most suitable is ex post facto research under a co-relational design (2007). Ex post facto research method is used if the researchers are unable to conduct a controlled experiment. Instead of meticulously controlling and manipulating every variable before conducting the experiment, ex post facto research only requires data collection and data analysis to test the hypothesis. A co-relational design of ex post facto research is the research design used when the researchers cannot collect data for all variables. This design cannot test causal relationships but can prove correlation relationships.

Data Collection

To measure student learning a validated introductory CS test will be used. The students will take pre-tests and post-tests to measure the improvement in scores. At the early part of the semester x CS2 classes will take the SCS1 exam as a pre test. To generate the pck test, each test question in the SCS1 exam will be converted to a pck test question that would let the teacher identify from the SCS1 choices which are the most common misconceptions. An SCS1 post test will be administered towards the end of the semester and the improvement of scores from the post test will be measured.

Analysis

There are two available student test data after the pre test. One is from the pre-tests administered on the students teached by the teachers taking the PCK tests and another data available is from SCS1 pre tests taken by CS1 students from around the world. Because of the possibility that these two groups of data will show different frequencies of common misconceptions, teachers' answers will be marked based on the two groups of student test data. Pearsons r correlation will be used to measure the relationship of pck and the learning of students throughout the semester. Teachers' PCK scores will be correlated against the improvement of SCS1 scores of the students they are teaching. Correlation will be measured per test item and overall score as well. We can accept the hypothesis that the SCS1 can be used as an instrument for PCK testing if the students under higher PCK scoring teachers show larger differences in SCS1 post and pre test scores. Using the PCK test scores of the teachers, test items in which average scores are low will be chosen. The topics in which theses items belong to are identified as hard topics to teach.

Chapter 5

Conclusion

Computer science education is a relatively new field of research. There are so many studies in which we highlight how students learn CS and there are so many hypotheses on why they have difficulties on it. And while there are studies that investigate how we teach CS, our knowledge on CS teaching is thinner compared to our knowledge in CS learning. Because of that, this study focuses on the measurement of PCK; it is an emerging construct introduced by Lee Shulman in the 1890's.

PCK, the blend of pedagogy and content knowledge, is a knowledge base used by teachers to teach specific topics. It is a construct that is useful in investigating the unique ways in which we teach complex subjects like programming. While the concept of PCK is promising for CSED , data on CS teachers is hard to find. Teachers' PCK is a highly complex concept which can take different forms making it hard to measure. There have been many attempts to measure PCK there are several which focus CS teachers PCK. But these measurement methods prove to too complicated, too abstract, or too expensive. Because of this, we offer a simple, quantifiable, and cheap method for PCK measurement. Instead of measuring PCK directly, we focus on the manifestations of PCK, specifically knowledge on student misconception or KOSM. We use an established and validated multiple choice exam for CS students, the SCS1 exam, and repurpose it to measure teachers' PCK.

The methods introduced in this research can help CS instruction in many ways. The measurement tool itself can be a useful evaluation tool that can encourage improvement focused teacher training. The tool can be used to empirically measure teaching, giving us additional insights and which teaching practices and techniques are good and which are bad. The measurements provided by the tool can help CS curriculum by identifying hard to teach topics. Using the tools and methods introduced in this research we can learn a lot more on how CS teachers teach.

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