A Case Study of the Development of CS Teaching Assistants and Their Experiences with Team Teaching

Elizabeth Patitsas
University of Toronto Department of Computer Science
Toronto, Ontario, Canada
patitsas@cs.toronto.edu

ABSTRACT

Teaching assistants play a vital role in lab-based teaching at large institutions, with a large impact on students' success in CS1. How do TAs develop as teachers? We extended existing models of teacher development for our context of teaching CS labs in pairs. We found practice, teaching multiple courses, mentoring, effective staff meetings, team teaching, and feedback all contributed to TAs' development. Team teaching was a positive experience for our TAs, and allowed them to learn from each other. While teaching labs, TAs learnt mostly from partners who had more course-specific experience, rather than general teaching experience.

Categories and Subject Descriptors

K.3.2 [**Computers and Information Science Education**]: Pedagogy, education research

General Terms

Human factors

Keywords

Computer science education, teaching assistants, labs

1. INTRODUCTION

Consider the scene: a lab session has just ended. The TA hangs around, to debrief the lab with another TA. While mundane, for TAs this is a valuable source of professional development – yet this is ill-studied. How do TAs hone their teaching skills? Who and where do they learn from?

At the University of British Columbia (UBC), CS is taught by 55 faculty and about 200 TAs. The TAs are responsible for over half of the contact hours in first year CS, and, with the lower student-to-teacher ratio, are positioned to have a large impact on their students.

In this paper, we provide a case study of the experience and instructional development of the TAs in CS at UBC. We are interested in how to improve the teaching of our TAs – how can we most effectively and efficiently support our TAs?

Note that this is a case study; while TAs are important to how CS is taught at our institution, our heavy use of TAs is not universal. We leave it to the reader to determine the relevance of our context to their own.

Koli Calling '13, November 14 - 17 2013, Koli, Finland.

ACM 978-1-4503-2482-3/13/11 ...$15.00.

1.1 The Importance of Teaching Assistants

We know from the small literature on lab TAs that their teaching has an effect on student retention [1], and final exam scores [2]. Indeed, students' performance in TA-taught labs have been found to be a predictor of success on final exams in CS1 [3]. Studies in the general education literature on teaching assistants tend to document issues of (lacking) TA quality (e.g. [4]), often with little empirical guidance for how to improve the matter.

Our use of TAs is typical of research-intensive North American institutions, where first-year students spend 30-50% of classroom hours with TAs [5]. The use of undergraduate TAs in teaching introductory programming labs is also common to our type of institution [6, 7, 8], and has been found to be effective in providing a positive learning environment [6], particularly for women and other minorities. Effective use of TAs has the potential to improve the retention of women and minorities in CS, and reduce failure rates.

Despite TAs being highly used, they are not highly trained, and *"few faculty members set as a career goal the supervision of graduate teaching assistants"* [9]. In our experience, many faculty see TAs as poor at teaching; yet the evidence is that TAs – like all other teachers – develop with experience, feedback, support, and positive socialization [9, 10, 11]. Existing literature on TAs comes from the humanities and other fields without labs; as such, we must draw on those studies, and general teaching development, to inform our understanding of TA training and development.

1.2 Teacher Development

How do teachers develop and change professionally? Guskey created a model in 1986 of teacher change; in 2002 he republished his model with almost twenty years of empirical evidence for the model [12]. Guskey found that the naïve model that "*knowledge → change in attitudes/beliefs → change in behaviour*" is false [13]: change in attitudes/beliefs is unlikely to happen from solely informing people about new teaching techniques. Instead, change in attitudes and beliefs comes *from* a change in behaviour. Guskey's simplified model looks as such [12]: *professional development → change in teachers' classroom practices → change in student learning outcomes → change in teachers' beliefs/attitudes*

As we see here, the change in beliefs comes from a change in behaviour (the classroom practices). So what prompts teachers to change their classroom practices? Teachers are highly motivated to improve their practice – but are wary that changing their approach could potentially result in *less* student learning [12]. Teachers who have had success changing their practices in the past are more confident about further changing their practices [12]. For effective professional development, teachers need to receive regular feedback, and receive *continued* support that is understanding of the fact that change is gradual and difficult for teachers [12]. It is hence not surprising that coaching approaches to teaching

development are staggeringly more successful than isolated, one-time tutorials on pedagogy [14].

Kugel, in his paper on how professors develop as teachers [15], observed that the teaching abilities of professors develops in stages. He presented three stages of development:

1. *Focus on self* and their own role in the classroom
2. *Focus on subject material*
3. *Focus on student* and their ability to absorb and use what they have been taught

In his paper, he breaks the third stage into three: a focus on students' ability to absorb knowledge, a focus on students' ability to use what they have been taught, and a focus on students' ability to learn independently [15]. These three sub-stages are empirically difficult to separate and for the purpose of our paper, we will be treating them as one stage.

Kugel also presents how professors transition between these three stages. The first transition happens once the professors develop confidence that they are not talking too quickly or quietly, or covering too much/little material, etc – and from there, begin to worry that they are not doing a good enough job of teaching the material. In the second stage, professors increase the quantity of what they teach as they develop enthusiasm for the material – and then begin to wonder why students fail to understand all the new material, blaming this on the students. In the second transition, professors begin to focus on the students themselves.

Kugel's transitions are consistent with the research that behaviour change leads to attitudinal change – but his described transitions are simplistic and focus only on the professor. What external forces act and help the teacher to develop? We know that knowledge transfer among teachers is "pull transfer" – teachers pull on their colleagues for aid when they see a problem – rather than "push transfer" [16].

Sprague [9] and Staton [10] describe two external forces that affect TA development: supervision, and socialization. Sprague has a three-stage model of TA development that parallels Kugel's model. She focuses on how TAs should be differentially supervised depending on their stage of development; it should be noted her model comes from an arts background, with no labs.

1. *Senior learner* – a new TA, who is making the transition from being a student to a teacher (focus on self)
2. *Colleague in training* – "as TAs settle into the new role, they become more concerned about their lack of teaching skills" [9]; it is at this stage that they begin to develop a teaching style and focus on delivering the content (focus on subject)
3. *Junior colleague* – "their primary concerns involve discovering ways to help students learn ... [they] are able to transcend, combine, and create systems of instruction ... they are just the people we would all like to hire as assistant professors" [9] (focus on self)

Sprague argues for "progressive delegation" of tasks to TAs – giving the junior colleagues more responsibilities (such as running tutorials), and the senior learners fewer ones (grading papers). Importantly, she notes that the supervision of these TAs should also change: senior learners need a manger; colleagues in training need a role model; and junior colleagues need a mentor [9]. TAs at all stages can benefit highly from feedback and effective supervision – and from relationships with other TAs. Senior learners need a support system of fellow TAs/co-learners; colleagues in training need the fellow TAs as resources; the junior colleagues act as mentors and role models to the other TAs [9].

Per Staton, *"new friendships are a vital component of the TA socialization experience. In fact, having a group of people with whom one can share concerns, fears, triumphs, and challenges ... can make a considerable difference in later success as a faculty member."* [10] For new TAs, it is vital to their development to have friendships with new TAs and senior TAs as role models. TAs are also affected by the culture of their department: micro-messages from fellow students/faculty about the importance of teaching make a large difference [10].

Insufficient social support for TAs is a common issue [5, 4]: TAs tend to feel "overworked, underpaid, and unappreciated" [5], and faculty are unmotivated to focus on TA supervision [9]. A positive social environment for TAs makes a large difference in their motivation as teachers, and their quality of teaching as a result [5].

1.3 Social learning and knowledge transfer

Social learning, also known as observational learning, occurs through observing, retaining and replicating new behaviours seen by others. It is one form in which *knowledge transfer* (distribution of experiential knowledge) may occur [17]. Szulanski identifies three factors in knowledge transfer: the ability of the recipient to identify, value, and apply new knowledge; the depth of knowledge of the source and their usefulness as a role model; and the ease of communication and intimacy of the relationship [17]. As such, we would expect more experienced TAs and course instructors to be more useful sources of knowledge transfer – and more transfer to happen when TAs have more social support.

2. CONTEXT

At the time of this study, UBC CS TAs teach labs in pairs. Lab sections typically contain 20-30 students, and last 2-3 hours depending on the course.

There are 60 undergraduate TAships every year, and 150 graduate TAships. Graduate students are mostly first-year MSc students hired as part of their guaranteed funding package; more experienced graduate students can apply for additional TAships. These experienced graduate students, and the undergraduates, are hired selectively.

In this study we are focusing on TAs who teach first and second year CS. These courses are large; they have hundreds of students, 1-4 instructors, and dozens of TAs. Typically these courses have weekly staff meetings; first-year courses will often have TAs perform the labs in advance during these staff meetings. The organization of the staff meetings varies depending on the lead instructor for the course.

New TAs are strongly encouraged to attend an initial training session. While TAs are told it is obligatory, in practice, TAs frequently skip the session without recourse. No further formal TA training is available to TAs.

The convention in TA assignment is to place TAs who have been hired previously onto the course they had last taught, in the hope of maximizing the experience on a given course. As a result, the vast majority of two-term TAs have only taught one course. More experienced, sought-after TAs have more leverage to request shifting to new courses.

3. METHODS

We held hour-long, semi-structured interviews with nine TAs, using the data to refine Kugel and Sprague's models of development to a model of TA development in our context.

TAs were sampled to yield a maximal spread of experience. We interviewed two first-time TAs, four second-time TAs, two fourth-time TAs, and +6-time TAs. Given the high turnover of TAs in our department, finding TAs with more than three terms of experience is difficult; we had hoped to have a second +6-time TA but were unsuccessful to find one that satisfied our constraint of only interviewing TAs that the author had not worked with[1]. We list our participants in Table 1; names have been changed.

[1]This proved to be a substantial constraint: the author had been a prominent TA for nine terms.

Participant	Terms as a TA	Courses TAed
Alice	1	1
Arthur	1	1
Bob	2	1
Ben	2	1
Bill	2	1
Charlie	2*	1*
David	4	3
Daniel	4	3
Evan	6	3

Table 1: Summary of participants by experience; Charlie has significant additional non-CS teaching experience as a sports coach

3.1 Interviews

The interviews began with a *grand-tour question*[2], an open ended question which allows the interviewee to set the direction of the interview [18]. We would ask the TAs to list their experience, including all the different duties they had had over the years. From there, example questions we asked were (in typical order):

- Why did you become a TA?
- What do you see your role as being as a TA?
- What is your favourite part of being a TA?
- What is your least favourite part of being a TA?
- Who has influenced you as a TA?
- How were you trained for your job?
- What do you do to prepare for the labs?
- Have you sought advice from others about TAing?
- How many lab sections have you taught? Could you describe each one?
- Who did you teach those lab sections with? What was your experience of working with them? What was your first impression of them?
- What do you think of your own teaching ability?
- Has your teaching style or ability changed since you began? How so?
- Overall, how would you characterize your experience as a TA?

3.2 Qualitative analysis

The interview analysis happened in multiple stages, using an Affinity Diagram [19]. Our goal at this point was to examine these research questions:

RQ1. How does the TA experience change with development? (section 4)

RQ2. What influenced our participants to transition to new stages, and promote their development? (section 5)

First, interviews were transcribed. Then, each interview was coded: each new theme, idea, or issue was summarized on a post-it note. Post-it notes were colour-coded by the participant and the amount of experience they have. Once all the initial codes were put on post-it notes (approximately 300), the post-it notes were iteratively grouped by theme, until there were approximately 25 groups.

Then, for each thematic group, we took the post-it notes in the group and sorted them by how experienced the TA was: Alice/Arthur, then Bob/Ben/Bill, then Charlie, then David/Daniel, then Evan. We decided that since Charlie has more teaching experience than Bob, Ben and Bill that we would analyze him as a separate category.

We split thematic groups into two categories: those where a TA's experience of that theme changed with how experienced they were (e.g. asserting authority was hard for Alice/Arthur but easy for Evan), and those that did not (all TAs looked up to course instructors).

Using the themes which changed with experience, we looked at when the changes happened, to identify when stages of development begin/end; and fitting to Kugel's and Sprague's stages in a data-driven approach. Once we had fit our participants to those three-stage models, we looked at what factors influenced our participants' transitions.

3.3 Additional analysis

As one of the factors which emerged as influential was team teaching in the lab, and there was no existing literature on how TAs teach in teams, we focused more on this. We then added these questions:

RQ3. How do TAs work together in pairs? (section 6)

RQ4. How does knowledge transfer flow? (section 7)

We performed 8 hours of observational study of TAs in their labs, observing how pairs worked together (described in [20]). After these observations, we went back to the interview scripts, and re-coded participants' answers about how they work with their partners and their experiences with their partners. For these two research questions, the unit of analysis was the pair. From interviews, we had descriptions of 23 pairs; we also had observed 4 pairs in the lab.

4. WHAT CHANGES WITH EXPERIENCE

4.1 Confidence

More experienced TAs described their own teaching ability more confidently, particularly in terms of asserting their authority and forcing the students to work. As the most experienced participant noted, *"I think I've gotten more stern [over the years]... now I'll enforce a sort of 'put in the effort' to the students. I have a policy of never giving students 'The Answer', and many students don't like that; I can tell students aren't happy about it... at this stage, it gets frustrating, not holding students' hands as much as I used to. I'm not as popular, but always respected." (Evan)*

The TAs with four or more terms of experience were comfortable asking students to, as one put it, *"eat their spinach"*. As Evan describes, *"I may not be popular, but I always feel respected"*. The newer TAs were less comfortable with this. Alice, a first-time TA, described her teaching ability as "hit or miss"; and a second-time TA rated his ability in the classroom as *"better than having no TA there." (Bob)*

The aspect of increasing self-confidence manifests itself elsewhere, such as in interacting with students. Overall, experienced TAs considered themselves to do a better job of teaching, particularly compared to when they began.

4.1.1 Regular Preparation

We saw three stages of TA preparation based on experience: diligent but potentially ineffective preparation, overconfidence, and then effective preparation.

Alice, Arthur, Bill, Ben and Bob all described diligently preparing – looking over labs, but not necessarily doing the labs themselves. They would identify where they expected students to have difficulty. Not having much experience teaching these labs, this was based mostly on their own experiences as students.

For Charlie, David and Daniel, the TAs who had taught more than one course, the days of worrying about lab preparation were behind them. Instead, they would describe times

[2]Typically, "What has your experience been like as a TA?" Alternate wordings were used.

where they neglected to prepare for their labs, assuming they could "wing it" based on previous experience. With their increased confidence, their jobs became easy: *"it was so simple it [preparation] didn't really matter at all" (Charlie)* but later noted that *"I had a problem with preparing for [the labs], out of hubris for having done the labs... one time where I was doing something completely wrong and [my partner] caught me... the preparedness thing was something I could have worked on... [In time] I tried to detach myself from my ego." (Charlie)*

Teaching a course multiple times also would make it harder to motivate onesself to prepare: *"when you've taught the material a few times, and you remember that you've taught it, you have to bring yourself back to the point where you didn't know it, and you have to reset it." (David)*

Evan described himself as reliably preparing. His preparation was less than the first-time TAs, but more targeted; he could identify when he needed preparation, and when he did not. Noticeably, only Evan, David and Daniel mentioned talking to fellow TAs outside of lab as a source of preparation – for the more junior TAs, preparation was generally a solo experience.

4.2 Technique

4.2.1 Approach and Focus

When first-time TAs assessed their own teaching ability, they would describe their approaches to answering questions. One described her approach as: *"I try to simplify it, try to break it into steps. Sometimes I'm leading the person to the answer and sometimes I think I'm dragging them to the answer ... If they don't get it, I try to take them back to where they last understood, and take them from there. It's hit and miss." (Alice)*

The second-time TAs would also focus on answering questions, but described their ability to do so as successful, and focused on the content of the questions – whether they could answer a question on HTML, or how to use the debugger in Eclipse. For both the first and second-time TAs, their evaluation of themselves was largely based on how well-received they were by the students. The first-time TAs were clearly at Kugel's "focus on self" stage, but Kugel's model doesn't quite fit here for the second stage. The second-time TAs were comfortable with their ability to answer questions, and focused on content (focus on subject) – but evaluated themselves based on how students perceived them (focus on self). Here is where Kugel's model doesn't quite apply to TAs – we think it is because they do not determine the subject material, and have less responsibility for it, and so it is harder for them to focus on only the material.

Charlie, David, Daniel and Evan also described using multiple ways of reaching their students. They would lecture the class, or target students and "guide them along" rather than waiting for those students to ask questions. These four TAs described multiple heuristics in teaching students, shifting between them as appropriate. They were the only ones describing a Socratic approach – *"I don't give them answers, I just get them to find answers." (Daniel)* They described their approaches as focusing on equipping students to learn independently, and would evaluate themselves based on their impression of student learning. By Kugel's model, these four TAs are at the "focus on student" stage.

4.2.2 Communication skills

The more junior TAs (Alice, Arthur, Bill, Bob, Ben) also tended to discuss their communication ability when describing their teaching ability. For example: *"one person wrote [in my evaluations that] I should take some public speaking lessons, and maybe I should, and it's a bit hard for me in front of the class but it's easier one on one. There were also a few cases where I might have misled someone." (Bob)* – And: *"[My teaching ability has] room for improvement... I have to make a mental effort to slow down when speaking to students" (Arthur).*

In contrast, the more senior TAs (Charlie, David, Daniel, Evan) did not mention their communication ability when assessing themselves as teachers. They did not note difficulty in communicating with students, although note was made of improving over time: *"[Teaching is] a great experience... it's an experience for growth. You have to know things to quite a high level unlike [teaching sports], and you're developing it at the same time as you're developing the soft skills." (Charlie)*

4.3 Interactions with Students

4.3.1 Relationship to Students

All participants noted that their favourite part of their work was helping their students, and guiding them to so-called "Eureka moments".

For junior TAs, interacting with students in a friendly manner was important. They were also eager to have more interactions: *"what is important is that I get more interaction with students." (Ben)* And as another put it, *"[My favourite part about being a TA is] I get to interact with the same group of students, so you develop a friendship sort of thing. It's fun knowing they can turn to me when they need help in lab." (Alice)*

For the more senior TAs, interacting with students in a mentorship style was more important. One wanted *"to convey that CS is pretty cool, and when students get it, that's a pretty good feeling" (Evan).* Another said, *"I don't chat with the students or [my partner] socially [while teaching]" (Daniel)* and that during lulls in the lab, he would instead focus on the struggling students: *"[it] takes out a lot of my time to try and help them." (Daniel)*

The difference between the mentorship approach and the friend-making approach could sometimes cause tension between TAs of different stages. For example, in describing his less experienced partner, Charlie described that *"[The partner] would spend more time talking with the kids, talking about random stuff ... there was a couple [of students] that he really liked to chat with. I would also chat with the students, but not as much as he did. As a TA you want to be friendly and nice, but you don't want to have a 20 minute discussion about your favourite video game." (Charlie)*

4.3.2 Authority

Asserting authority was a salient problem for the first-time TAs, particularly given their young age: *"As a first year [myself], it's weird interacting with students in first year who are in classes with me, and with older students ... My position as an authority is a bit [pauses] I have to be a bit more careful in what I do." (Arthur)*

Arthur and Alice's descriptions of their unclear authority in the lab was very much consistent with Sprague's description of the "senior learner": *"they tend to identify more with the students in their classes than with the instructors they are assisting ... this is a troubling and confusing transition[:] Can I really do this? Do I look like a teacher?"* [9]

Bob, Bill and Ben were more comfortable in their roles; they could assert authority when they had to, and were generally unworried about whether they were seen as authorities to their students. And for Charlie, David, Daniel and Evan, this was not an issue at all.

Related to this is how TAs would respond to questions where they did not know the answer. More senior TAs generally responded by calling over their partner to see if they knew the answer – regardless of how experienced their partner may be. As one put it, *"If there's something I'm not confident on, I'll refer to [my partner] – we want to get the*

best answer possible [for our students]." (Daniel) Junior TAs were less likely to defer to their partner. They were less likely to admit that they did not know something, worrying that they would look incompetent. For example, Ben noted that if a student asked him too advanced a problem, he would brush it off rather than ask his partner.

4.4 Support

4.4.1 Teamwork

First-time TAs tended to ignore their partners, "too busy" while teaching to check in with their partners or observe their work. Second-time TAs, however, tended to interact directly with their partners, such as in socializing with them or intentionally observing how they answered questions. Junior TAs were immediately trusting of their partners; as one noted, *"It was kind of implicit – we never thought of it. It was a given. We were both in the same section, we were both TAs. What was there not to trust about?" (Ben)*

For more senior participants, the trust was to be earned. Some would report experiences working with unprepared TAs where they had to perform "damage control"; these experiences tended to stop TAs from automatically trusting their partners. The senior TAs would take more of a supervisory role when paired with an inexperienced TA, taking them under their wing. Evan describes a partner: *"[She] was frequently unprepared as a TA [last term]; this impression [of her] has not changed. [This term] She is more comfortable with the material now, can think on her feet more. ... I trust her now more since she's more familiar with the material... not so much when first TAing with her, wasn't sure she'd always give good advice to students." (Evan)*

The senior participants would take the initiative to communicate with their partners about the lab, such as in discussing the lab beforehand, or debriefing together afterwards. For one, the process was: *"[We] would huddle up and talk the lab over... same thing with [a partner in another section], huddle up at the beginning to talk about what the lab is about and who does the marking" (Daniel).* Another TA used the lulls for this: *"when there's a slow period, and nobody asks a question, then we'll talk until somebody asks a question. It was actually pretty neat to see how he [the partner] was doing the labs." (David)*

4.4.2 Getting Advice and Encouragement

Beyond their partners, all participants sought advice and support for their work, and found mentorship important in their growth. Participants of all stages looked to their course instructors for mentorship.

Novices also went to external sources: friends, family, and past TAs were noted. The senior TAs noted going instead to more experienced coworkers and their research advisors.

When asked about their favourite part about teaching, the more experienced TAs noted collaborating with the other staff as a favourite part about teaching. One, for instance, noted that staff meetings were one of his favourite things, and that *"I really, really enjoy working with [two course instructors]. Our staff meetings are awesome." (Charlie)* This was not noted by the junior TAs.

Outside the labs, TAs of all stages would also seek advice from other, experienced TAs. *"At one point I asked another TA [Daniel] about another lab. I was wondering how they handled people who couldn't keep up. [And how to handle a difficult student.] And I did ask some other TAs to ask what their experiences were like, and I could use that to generate a strategy to work with him." (David)*

Similarly, Arthur went to his TA from when he was a student (Charlie) for advice about students not finishing labs on time, and was reassured that *"it's not your fault they didn't all finish on time".*

4.5 Perception of the Job

4.5.1 Least Favourite Parts about Teaching

While no TA enjoyed seeing their students fail, nor fail to complete on time, nor having students who didn't put in the effort or keep up with the material, the extent to which these things distressed the TAs differed between the junior TAs and senior TAs.

Alice, Arthur, Bill, Ben and Bob found these issues highly distressing, listing them as their least favourite parts about teaching. By contrast, the senior TAs described these matters with a large degree of acceptance. Indeed, on the matter of students not finishing on time, Alex noted a "too bad, so sad" approach; he would cut labs off precisely on time to be fair to all the students.

Senior TAs listed a number of different things in response to "what is your least favourite part about teaching?". These were: 8AM staff meetings, bad answer keys, issues with recording grades, and managing grades with Blackboard; in other words, logistical issues that differ from term to term. Senior TAs tended to focus on complaining about matters they felt could be changed — such as rescheduling staff meetings, or changing the course management software.

4.5.2 Triage

Senior TAs demonstrated more incisiveness in how they allotted their time and effort as TAs. As Evan noted, *"in my first term, I would not have thought twice about spending 40 minutes with a student that hasn't put in the effort..."*

Junior TAs did not note this discrimination: *"I'd often stay up to an hour and half [overtime]... The labs were tiring since they were 3 hours, and most students took half that time. Some 'exceptional cases' took longer, and I'd wind up working overtime. I'd spend a lot of time working on false problems: ambiguous instructions, lab machine issues, so on – I'd be wasting a lot of time on these." (Ben)*

When it came to the 'exceptional cases' of students who were very far behind, the senior TAs described a form of triage in rationing their time, and learning to move on for students that "can't be helped". None of the junior TAs mentioned passing over these students, instead devoting as much time as they could to them.

Junior TAs struggled with overexerting themselves, like that TA who would be spending extra hours in the lab helping students. In contrast, one senior TA would *"not stick around after the lab; it reduces cross-pollination between sections and is more fair to the class [as a whole]... I get told I come off as unfriendly, but I'm working on it... when students come in late I won't repeat earlier explanations, to enforce timeliness." (Daniel)*

4.5.3 Motivation and Role as a TA

When asked why they became TAs, the chance to help others always came up. Junior TAs, however, tended to note benefits to themselves: the pay, getting job experience, practice at communicating, and consolidating their knowledge of the material. Senior TAs tended to focus more on philosophical reasons — to "pay it forward", to make up for *"the bar being set so low"* in terms of TA quality, and to replicate the effect that an influential TA had on them as a young student. It is plausible that the TAs who teach for these reasons are more apt to gain more experience.

When questioned about what they see the role of a TA as being, senior TAs tended to describe the role first as that of a teacher and role model, and secondly as that of an assistant to the course as a whole, while junior TAs tended to describe the role primarily as an assistant to the instructor, reinforcing their work in lecture.

As one first-time TA put it, *"We all want to get these kids through the lab and get them through as best as we can. I*

see my job as clarifying what students are having difficulty with, reinforcing what they're learning in lecture. By doing things, they learn it better; helping them see why they'd do something." (Arthur)

Being a role model was a theme in the senior TAs' answers; *"We are on the front lines, we are the ones the students see; they make their impressions based on us. And it's our task to make sure they learn the stuff, and I'm willing to spend extra time to make sure that's possible. And on the flip side, we also have to make sure things run smoothly, so the professors don't have stuff to worry about." (David)*

5. FACTORS PROMOTING GROWTH

5.1 Practice

For the Sr. Learners, teaching gets less "intimidating" as time proceeds and they gain more practice at it: *"[Teaching] was really scary at first... it is about people skills... but not as hard as I initially thought it would be ... I started off being very math-heavy; now I'm trying to draw from a wider range of examples and different ways of approaching the problem." (Arthur)* and *"over the course of the term, the labs became less intimidating" (Bill)*

One Jr. Colleague described that *"this term I'm much more comfortable" (Daniel)*, referring to his fourth term. In contrast: *"[For my first experience] I was nervous... I expected it to be harder, and eased into it after a few lab sections, and y'know, developed confidence about it, like 'sure, I know this stuff'. It wasn't too bad. [The term after,] I switched to [a second course] to get some variety and to work for [a particular instructor]." (Daniel)*

In addition to the day-by-day practice, TAs also used their term-by-term experience. For example: *"[I] made a point of learning students' names in the first week this term ... it felt awful handing students the marksheet last term [when I did not know their names], especially when most of them knew my name." (Bill)*

5.2 Teaching a Different Course

While Sr. Learners described their first terms as TAs as "intimidating", the more senior TAs described switching to a second course as their most challenging experience, and that this was harder than than beginning as a TA.

Indeed, the senior TAs all noted the experience of moving to a different course as pivotal in their development; their first and third courses were less discussed in this regard. Indeed, having taught multiple courses appears to be the distinguishing factor between the Colleagues in Training and the Jr. Colleagues.

As one Jr. Colleague notes: *"[My first experience as a TA] was fun. Felt prepared, since I'd done well at [the material] at both the grad and undergrad level ... the next one I TAed was CSXXX; It was a different experience. [...] since the course material was new to me. I had to learn the stuff in advance to be able to teach it right back." (David)*

For another: *"[When I first TAed the second course] I was nervous, especially around [the course instructor] ... It took me a term to get used to [that course], there is a special way of doing things [compared to his first course].." (Evan).*

The process of having to adapt to a new way of teaching, and new material, made the Jr. Colleagues reflect on their teaching and generalize their skills to the new courses. It also counteracted the "boredom effect" of teaching the same material repeatedly, and encouraged David and Daniel to prepare for the new material (cf. subsubsection 4.1.1).

For the Colleagues in Training there was a desire to try a second course. *"I was getting tired of the course [by the time I applied for a second TAship]... I plan on continuing to TA for as long as possible ... Hopefully not [the course I'm on]. I don't want to be in the same course for too long; I want breadth of experience. Actually, I listed in my preferences everything but [the course I'm on] for this term." (Ben)*

The Sr. Learners, in contrast, reported not feeling "ready" to try another course: *"I don't think I'd be qualified to teach anything else." (Alice)*

5.3 Mentoring

Our participants reported mentoring as being helpful in their growth – and for Evan, being a mentor helped him. Mentoring could come from course instructors, research supervisors, or more experienced TAs.

Indeed, numerous study participants reported going to Evan for advice, or listening to his remarks in staff meetings. He was also aware of being a role model: *"there is a 'social strata' in [this] course, once you've done it once before you're in [the 'old folks'] crowd. Among that crowd, I think I'm the only one whose done the course for more than one term... Now, TAs will ask me questions and expect a definite answer. I'll try to be hands off with the 'new folks', I don't want to give them the impression that I think they can't do it." (Evan)*

For the graduate student participants, research supervisors were noted as role models, among others: *"I have been influenced by many teachers: [my research supervisor] has been especially influential; I also had another mentor... she has passed away... she helped me deal with many things that come to you at once, and make all the students feel acknowledged and not feeling ignored. And I'm learning a lot from [the two course instructors] and I learnt a lot from [one of the course instructors] by watching him and how he handles questions." (David)*

5.4 Working with other TAs

5.4.1 Staff meetings

Staff meetings form Sr. Learners' primary resource for advice on labs, and were noted as very valuable to them. These TAs tended not to actively contribute to the meetings, but listened carefully to the discussions between the other TAs and the instructors.

Arthur described their training for the job as: *"There were pointers on how to run the lab [at the staff meetings, which] came from the other TAs as a general discussion... At the meeting, the main contributors to the warnings [about pitfalls] include Daniel and David, but everybody tends to pitch in. [The course instructor] talks about the labs [also.]"*

The other Novice adds: *"I don't surround myself with other TAs [off the job] ... so I don't really get influenced by them... At the meetings, [the course instructors] will give tips and I'll take notes and try to use them ... One time I brought up that my students were working together in lab and one student was just copying. I brought it up in one of our TA meetings and they gave me some helpful pointers... mostly when we have TA meetings I listen to other issues that are brought up, so it's okay in that sense. " (Alice)*

Hearing their coworkers talk about teaching appears to support Sr. Learners in reflecting about their teaching. Alice noted: *"[Since the start of term] I've become more self-aware. At the beginning, I was more telling them the answer, now it's more I'm telling things to get them towards to the answer. I ask them questions to get them engaged... I've become more aware about how I approach things." (Alice)*

5.4.2 Team teaching

For Colleagues in Training and Jr. Colleagues, team teaching was noted as useful for gaining tricks, examples, and advice on how to teach the labs. For Ben, talking to their partner was enjoyable and motivated preparing for the labs: *"[My partner and I] would let the students go crazy with the*

labs and we would sit at the front." They'd try out things on their computers. *"I would do little projects, and we'd share. It was fun, talking to [my partner] in the lab. We'd be talking about things outside the students' league, like assembly programming. But we would also be doing stuff related to the lab. And then we would try to do the lab, too." (Ben)*

Bob found that working with a much more experienced partner in one of his sections helped in learning the labs: *"I thought that [one of my partners last term was] pretty good. I would put myself at the same level [of teaching ability] as him had I not the lab with [a more experienced partner that term] and access to what she was doing. I could see how she would explain things; I could correct myself more often. Helpful in filling gaps in my knowledge."*

Evan, in reflecting on an earlier term as a TA, recalled *"It was nice to have [the other TA] around to use as a gauge of whether [our course instructor] was being stern or upset; I was nervous the first time I was on [that course], especially around [that instructor]." (Evan)*

As we noted previously, Sr. Learners differed from the other participants in how little they reported interacting with their partners in the lab. Indeed, Arthur, who hadn't reported talking to his partners much, noted during the interview's debrief that *"in doing the interview, I'm reflecting on what I'm doing and not doing in the lab... I think I should start talking to the other TAs more." (Arthur)*

5.5 Feedback

Sr. Learners reported being hungry for feedback, finding it useful for their growth. We have already noted mentoring – one source of feedback. But for TAs at our institution the only formal performance feedback TAs receive is from end-of-term student evaluations.

A number of participants noted the qualitative feedback they had received from students. For example, *"I would have my laptop out and not be disturbed for an hour, hour and half ... [My TA] evaluations described me as ignoring [the students], that they didn't feel comfortable interrupting [me], so I changed this in later terms." (Daniel)*

Rarely, instructors would give performance feedback in staff meetings, such as "you are all doing a great job". TAs described this as useful, particularly for being motivated midway through the term. One-on-one feedback from instructors was described as particularly powerful.

As students were the main (if only) source of performance evaluations, Sr. Learners tended to focus on pleasing their students. They worried that poor evaluations would lead to them not being rehired, and were intimidated to take a firm hand with their students as a result. Jr. Colleagues did not note this intimidation; after being rehired numerous times they had confidence in their job security.

6. HOW TAS WORK TOGETHER

As team teaching influenced TAs' development, and is unstudied in the literature – how do TAs work together?

The TAs responded unanimously that working with another TA in the labs was a positive experience; as one put it, *"the two TA thing was perfect" (Charlie)*. None of the TAs would have preferred to work solo, and reception to adding a third TA to a lab section was generally lukewarm: "*adding a third TA would make it harder to coordinate ... there might be more conflict.*"

Only Daniel thought that adding a third TA may be better: *"I've always wondered how it would go with three TAs instead of two; it would reduce the wait time for students, which is their biggest complaint. A third TA would give them time to sit down and help them out."* But as Bob put it: *"That size lab felt pretty hectic... we were just trying to keep track of everyone, so I think two is kind of ideal."*

The student-to-TA ratio (25 students to 2 TAs) was consistently described as manageable, except in CS1 – TAs noted the relative neediness of students in this course compared to other classes meant that the student-to-TA ratio was slightly too high. The CS1 labs also require students to show intermediate work to TAs at specified "checkpoints" and to wait until they have TA feedback before proceeding. More experienced TAs on the course would ignore the instructor's instructions about the checkpoints and let students work ahead after finishing checkpoints, so that there would not be bottlenecks in questions.

6.1 Advantages of Team Teaching

Our participants noted four benefits of team teaching:

Division of labour: *"makes the lab more efficient"*

Security: *"It's nice to have somebody covering your back"*

Teamwork: having another TA to socialize with during lulls, or *"bounce ideas off of"*

Diversity: *"sometimes you just can't see something and you need another view"*; *"we could combine our knowledge"*

For less experienced TAs, the last point was particularly salient: if they did not know how to help a student, their partner would be there to help them out – when their partner "has their back" it is making up for their own lack of knowledge or experience – and would give them a chance to fill those gaps, as we see in subsubsection 7.1.2.

For experienced TAs, a partner who "has their back" often meant they had more freedom in how they spent their time in lab – *"More TAs mean you can get to a student faster, or you can spend more time with a student and somebody else takes up the slack."*

6.2 Conflict in the Lab

Overwhelmingly, TAs had positive things to say about their partners and the experience of teaching in teams. However, conflict could arise between partners.

The most frequent negative comment about their partners was that they had been blunt or insensitive to their students, and all came from the undergraduate TAs:

- *"I think he would have been great for fourth year, but first years are a bit fragile and he should smile more." (Charlie)*
- *"he could be insensitive... very straightforward about what he tells students about their mistakes. Won't sugar coat it. Students have told me they found him insensitive..." (Ben)*

Experienced TAs were most concerned about their partners' preparation and professionalism.

As for direct conflict between partners in the lab, the only issues that our participants noted as contentious have been (regardless of experience level):

Part marks: whether students were being marked too leniently or harshly – for many CS TAs, having thrived in a culture of yes-or-no marking, any subjectivity in marking schemes is uncomfortable, and TAs get little guidance on the matter.

Punctuality: when their partner was coming consistently late, or very late

6.3 Approaches to Teamwork

TAs spent most of their time in the lab working independently. Generally, TAs would brief with their partner at the beginning of the section and debrief at the end, only checking in with each other if issues arose. In labs with lulls in student questions, TAs would also talk to their partners during these breaks.

About half of the TA pairs went further than this, by either actively observing their partner, talking strategies in the labs, or socializing. As some examples:

- *"I would see how [my partner] would explain things ... we spoke more about the issues that were popping up and how we could resolve them."*
- *"[My partner] would sit at the back [and I at the front] and whenever one of us would see a question, the closest would go over and sort it out... at the beginning of lab we would huddle up and talk the lab over... what the lab is about and who does the marking."*
- *"It was cool to get to know him a bit more... [working together] is good. He's really enthusiastic about his stuff. He knows how to help most stuff, and when he doesn't, I've been able to help him out."*
- *"There are these two girls who sit in the front row who don't talk to [my partner and I]... we talk about this and what we can do about it."*
- *"[My partner and I] would do the labs together [as preparation so] that we wouldn't look so clumsy in front of the students."*
- *"Our styles complement each other; I explain things theoretically, and she explains things concretely."*

Generally, TAs would not get to spend much time talking to their partners – for the majority of sections the TAs were "going from one question to another" for at least the first half, and last quarter of the lab – but the brief interactions were described as very useful. We categorized the types of reported in-lab discussions between TAs as such:

Lab issues: problems and bugs in the lab
Solutions/prep: lab content and solutions
Strategies/stragglers: identifying students in need of special attention and how to help them
Social/'chitchat': socializing
Logistics: who marks what, "could I have the marksheet", having to leave early, who enters grades, etc.
Do not talk - language barrier
Do not talk - no chance: the TAs were too busy in the lab to talk at all

The chitchat, while off-topic, was useful for beginning TAs to form friendships with their colleagues – and made it more likely for TAs to talk about lab issues and strategies. Undergraduate TAs, in particular, noted spending time with fellow undergraduate TAs outside of class and forming a social support network with their colleagues.

7. KNOWLEDGE TRANSFER

In our interviews, we saw that most of the knowledge transfer received by TAs came from fellow TAs – through informal mentoring, staff meetings, and working together in the lab. For the first two types of interaction, the knowledge transfer generally happened from an experienced TA to a less experienced TA – the "grandmasters" were the sources of knowledge that other TAs would look to. Noticeably, TAs did not pay attention to whether a grandmaster was a graduate student or an undergraduate.

More junior TAs would also emulate other teachers as they developed a teaching style of their own. Often they would look to more experienced TAs in this regard, as well as the course instructors. Often, for the undergraduate TAs, the TA who had taught them in the course they were now teaching would still be accessible (or even still teaching the course). Such veteran TAs were more likely to be sources of advice, and were most likely to be emulated – *"Charlie was once described at a staff meeting as 'walking on water'... very likable, very approachable, helps you figure out what you were doing, easy to understand... I try to be like him, and try to show the same enthusiasm" (Arthur)*

7.1 Knowledge transfer in the lab

In our field observations, we observed that one TA would be dominant in running the lab. The students and the other TA would defer to this *alpha TA* as an authority; in observing behaviours, we saw this TA would give most or all of the announcements to the class, that the *beta TA* would ask more questions of the alpha TA than vice versa, and the alpha TA would spend more time speaking than the beta TA – both to students and to each other.

We noticed that a TA did not always have the same position in every lab section – a given TA may be alpha in one section, and beta in another. We did, however, notice that positions were stable within a pair – a TA who was alpha on the first day of lab would continue to be alpha. Furthermore, we noticed that novice TAs were in many cases alpha TAs, particularly when two novices were paired together.

When interviewing TAs about each of their partners, we asked the questions "would you ask your partner more questions, or would they ask you more questions?" and "would your partner give more class announcements, or would you?". We then quantified their response as such:

2 pt: "they ask me questions and I don't ask them questions" / "I give all the announcements"
1 pt: "they ask me more questions than I ask them" / "I give most of the announcements"
0 pt: "we ask each other questions equally" / "we split the announcements equally"
-1 pt: "I ask them more questions than they ask me" / "they give most of the announcements"
-2 pt: "I ask them questions and they don't ask me questions" / "they give all the announcements"

We then add the question score and the announcement score for each dyad: if the TA we interviewed was the alpha in the dyad, the score for that dyad would typically be about 3 pts; for a beta, -3 pts. No dyads had a score of 0.

For each dyad, we determined the TA's previous TAing experience to that section, with breakdowns by how many labs they had taught previously, whether those had been for that course, whether they had taken the course, and whether they had taught the course. We also determined the number of labs earlier in the week the TA had taught. We then used the `lm` package in `GNU R` to model the alpha-ness as a function of those different types of experience.

We found only two factors were statistically significant ($p < 0.05$): whether the TA had taught sections earlier in the week, and whether the TA had taught these labs before in previous terms. Whether the TA had taught the labs in previous terms was a stronger factor.

This fits with the cases we observed in which an experienced TA took on a beta role to a less experienced TA – their partner had more experience with those labs. Hence, we see two types of knowledge that TAs draw from:

General teaching knowledge: ability to teach; related to the Sr. Learner to Jr. Colleague axis
Course-specific knowledge: knowledge of given labs, relevant subject material, and how a given course works.

In the lab, TAs look to the partner with more apparent course-specific knowledge. In contrast, when TAs described who they sought advice from outside the lab, they explicitly selected for friends, colleagues and role models with more perceived general teaching knowledge.

7.1.1 First impressions

One question we asked TAs was about their first impression of each of their partners. We observed that the words used to describe this impression varied by whether they were alpha or beta, indicating that these roles are determined very early in the term. Charlie, an experienced TA, described a TA that he took a beta role to as, *"First time I got to talk to him, he was lecturing [to the class] already."*

Alpha TAs were typically described as "experienced", "organized" and "intimidating"; beta TAs were "quiet" and "uninterested" – but were usually seen more positively over time, particularly as inexperienced TAs "learnt the ropes".

7.1.2 Learning from the Alpha

For junior TAs, the beta role appears to be extremely valuable. TAs new to a course would learn from alpha partners in an informal and often unrecognized apprenticeship. A sampling of comments from beta TAs about working with alpha TAs reveals a transfer of knowledge:

- *"[During the lab] she would call me over when there were problems arising, so I could see them"*
- *"It was pretty neat to see how he was doing the labs. "*
- *"I like it better when [my partner] is around. Just because he knows what he's doing, because he's done the lab before. So if there's minor details I don't know, I can ask him. And if there's something I can't explain, then maybe [he] knows how to do it. And it's harder for me to do the challenge problems."*

A number of TAs that had beta roles earlier in the lab week would hold alpha roles later in the week. Bob was in such a role, and said: *"I would put myself at the same level [as my beta partner] had I not the lab with [my alpha partner] and access to what she was doing."*

7.2 Other Influences

After their fellow TAs, course instructors were mentioned as the most influential people on our participants' development. (Other sources of influence that came up were mentors, research supervisors, and friends.) The influence of the course instructor was not consistently positive. One TA noted one of the reasons he tried hard to be a good TA was because he was afraid of the course instructor's ire – *"[this instructor] doesn't suffer fools gladly." (Evan)*

Another TA described a course instructor as a negative influence that contributed to his job dissatisfaction – *"[this instructor] was really lax about standards... [this instructor] takes these breaks... there aren't clear instructions on what to do when [they] leave." (Ben)* Instructors who did a poor job of management, or were disinterested in supervising TAs, were identified as negative parts of their teaching experience.

For the TAs who noted course instructors as an influence on their work, staff meetings would come up as important times for them. One TA noted that their course instructor would praise the TAs during staff meetings for their hard work; three TAs noted they had received good advice during the meetings. David, who sat in on lectures, noted watching the instructor and how he handled questions to be inspiring.

It should be highlighted that two of the nine TAs noted that they had at one point chosen a TA assignment solely on a desire to work with a particular course instructor. Five of the nine TAs noted course instructors to be a factor when listing preferences for TA assignments.

8. DISCUSSION

As a case study, this work provides a rich view of the TA experience at our institution, useful for improving TA support. Some threats to validity that should be considered are the recall bias of the participants, and the filtering effect of which TAs are rehired. Our analysis used descriptions of experienced TAs recalling earlier times – which would not be as reliable as having interviewing them years ago. Also, at our institution, only generally dedicated TAs apply for TAships past their 2nd appointment: TAs more motivated to develop as teachers are more likely to gain experience.

Due to ethics reasons, the study author was the only person who coded the interview data – some bias in coding will be inevitable as a result. Were the study to be repeated from the start, we would have added more researchers into the coding process. Lastly, we should note the identity of the researcher likely had a (positive) effect in the interviews: by being a peer to the participants, we feel we had their trust; we feel TAs were as a result more open and honest during interviews. We speculate that had a faculty member run the study, we would not have heard anecdotes about being uninterrupted for "an hour, an hour and a half" or being "intimidated" by their course instructors.

8.1 Implications for Practitioners

8.1.1 Implications for TA Training

Based our findings, we highly recommend formally mentoring TAs – but realize that such mechanisms are time-intensive and difficult to maintain. For most CS departments, we expect they would get better results by instead improving their TA training. We suggest:

- Offer *two* TA training courses. One for Senior Learners (those who have not taught before), and one for Colleagues in Training (those that have).
- Training for Sr. Learners should focus on communication skills, asserting authority, and triaging student questions. This is also a place to teach TAs how to use the department's chosen technologies for grading and handin, navigating the computing resources for undergraduates, etc.
- Training for Colleagues in Training should focus on pedagogy, effective teamwork, and preparation.
- Both groups benefit from teaching observations, though the focus on where to improve will differ.

8.1.2 Implications for Instructors

We recommend that instructors pair TAs for teaching labs. The social support provided by team teaching benefits all TAs. We also recommend running weekly staff meetings where TAs can discuss past and upcoming labs.

Positions of leadership – such as a Head TA position, or curriculum development – should be given to Jr. Colleagues. Courses that offer tutorials in addition to labs should prioritise assigning these TAs to tutorials. Office hours and grading should be given mostly to Sr. Learners. These TAs benefit from building confidence with the course material, and should be assigned a minimal number of lab sections.

In assigning TA pairs to labs, ensure each lab section has a TA that has either taught the lab before, or teaches another section earlier in the week. Course-specific experience is more important here than general teaching experience.

In running staff meetings, we recommend taking the time to give TAs feedback on their work. Solicit TA feedback on labs, and debrief together. We recommend viewing the staff meetings as a learning opportunity for TAs.

Large courses should also offer weekly staff meetings where the TAs work through the labs as a group, to help Sr. Learners with the material – and to ensure more experienced TAs prepare at all. These staff meetings should be run by a head TA – a Jr. Colleague – to encourage inter-TA collaboration (and to lighten the load for the instructor!)

Optimally, TAs would benefit from having one-on-one feedback from instructors as well as teaching observations from either fellow TAs, instructors, or external staff.

Finally – and perhaps most importantly – is that culture is important for raising TAs. Graduate students should be encouraged to do well at TAing by their research advisors. Course instructors should treat TA supervision as a TA mentoring opportunity. TAs will do better when they are encouraged from all sides to take the role more seriously.

9. CONCLUSIONS

We found that our participants' experience of development could be broken into three stages that followed Sprague and Kugel's models – although Kugel's second stage of "focus on subject" was less applicable as TAs do not determine subject material in our courses. We saw developmental differences in TAs along lines not predicted by either model:

1. Sr. Learners and Colleagues in Training were diligent at preparing for labs, but Jr. Colleagues could fall prey to underpreparing.
2. Sr. Learners were generally too overwhelmed in the lab to coordinate with their partners, and were too insecure to defer student questions where they did not know the answer.
3. Colleagues in Training, like Sr. Learners, were immediately trusting of their partners. Jr. Colleagues needed trust to be earned. Both Colleagues in Training and Jr. Colleagues coordinated with their partners, with Jr. Colleagues doing so in a more systematic fashion.

We found that practice, teaching a different course, mentoring, effective staff meetings, team teaching, and feedback all promoted TA development. For Sr. Learners, the staff meetings and practice were the most important factors; for Colleagues in Training it was team teaching, mentoring, and feedback. And for Jr. Colleagues, teaching a new course was a pivotal experience.

Team teaching was an important, positive experience for the TAs. For Sr. Learners it gave them security in the lab; for more experienced TAs it allowed for a division of labour, teamwork, and diversity in approaches. While conflict was occasionally present over ambiguity in marking, and professionalism, the experience of learning from another TA was clearly valuable for our participants.

Outside the lab, TAs sought advice from "grandmaster" (Jr. Colleague) TAs and course instructors, and saw them as role models. Inside the lab, however, knowledge transfer in a pair happened differently. In a given pair, knowledge transfer flows almost entirely from what we have termed the "alpha TA" to the "beta TA", and these roles would be fixed over the course of a term. A given TA may be an alpha in one pair and a beta in another pair.

Interestingly, which role a TA assumes is not related to their total TAing experience – but how much experience they have teaching a specific set of lab activities. Having taught the course previously, or even teaching a lab section earlier in the week, factors into which TA is the alpha. For example, we saw Jr. Colleague TAs taking a beta role to Colleagues in Training who had more course-specific experience.

It appears that TAs draw on two types of experience: general teaching experience, and course-specific experience – and both should be considered when assigning TA pairs. Instructors have the power to improve social support, feedback and mentorship for TAs – and should support TAs differentially based on their development.

10. ACKNOWLEDGMENTS

We would like to thank our study participants for their involvement, as well as: Meghan Allen, Patrice Belleville, Michelle Craig, Steve Easterbrook, Jon Pipitone, Kimberly Voll, Steve Wolfman, and anonymous reviewers.

11. REFERENCES

[1] Christopher O'Neal, Mary Wright, Constance Cook, Tom Perorazio, and Joel Purkiss. The impact of teaching assistants on student retention in the sciences: Lessons for TA training. *Journal of College Science Teaching*, 36(5):24–29, 2007.

[2] Cassandra Paul, Emily West, David Webb, Brenda Weiss, and Wendell Potter. Important types of instructor-student interactions in reformed classrooms, 2010. American Association of Physics Teachers Summer Meeting.

[3] Jens Bennedsen and Michael E. Caspersen. An investigation of potential success factors for an introductory model-driven programming course. In *Proceedings of ICER '05*, ICER '05, pages 155–163, New York, NY, USA, 2005. ACM.

[4] Valbona Muzaka. The niche of graduate teaching assistants (GTAs): perceptions and reflections. *Teaching in Higher Education*, 14(1):1–12, 2009.

[5] S. S. Bomotti. Teaching assistant attitudes toward college teaching. *Review of Higher Education*, 17(4):371–393, 1994.

[6] Eric Roberts, John Lilly, and Bryan Rollins. Using undergraduates as teaching assistants in introductory programming courses: an update on the Stanford experience. *SIGCSE Bull.*, 27(1):48–52, March 1995.

[7] Stuart Reges. Using undergraduates as teaching assistants at a state university. In *Proceedings of the 34th SIGCSE*, SIGCSE '03, pages 103–107, New York, NY, USA, 2003. ACM.

[8] David G. Kay. Large introductory computer science classes: strategies for effective course management. *SIGCSE Bull.*, 30(1):131–134, March 1998.

[9] Jo Sprague and Jody D Nyquist. TA supervision. *New directions for teaching and learning*, 1989(39):37–53, 1989.

[10] Ann Q Staton and Ann L Darling. Socialization of teaching assistants. *New directions for teaching and learning*, 1989(39):15–22, 1989.

[11] Robert D Abbott, Donald H Wulff, and C Kati Szego. Review of research on TA training. *New Directions for Teaching and Learning*, 1989(39):111–124, 1989.

[12] Thomas R Guskey. Professional development and teacher change. *Teachers and Teaching: theory and practice*, 8(3):381–391, 2002.

[13] Doug McKenzie-Mohr. Fostering sustainable behavior through community-based social marketing. *American Psychologist*, 55(5):531, 2000.

[14] John A Ross. Teacher efficacy and the effects of coaching on student achievement. *Canadian Journal of Education*, pages 51–65, 1992.

[15] Peter Kugel. How professors develop as teachers. *Studies in higher education*, 18(3):315–328, 1993.

[16] Sally Fincher and Josh Tenenberg. Warren's question. In *Proceedings of ICER '07*, ICER '07, pages 51–60, New York, NY, USA, 2007. ACM.

[17] Gabriel Szulanski. Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic Management Journal*, 17(Winter Special Issue):27–43, 1996.

[18] Del Siegle. Qualitative research, 2002.

[19] Karen Holtzblatt, Jessamyn Wendell, and Shelley Wood. *Rapid Contextual Design*. Elsevier, 2005.

[20] Elizabeth Patitsas. A case study of environmental factors influencing teaching assistant job satisfaction. In *Proceedings of ICER '12*, ICER '12, pages 11–16, New York, NY, USA, 2012. ACM.