



Extreme Apprenticeship: Instructional Change as a Gateway to Systemic Improvement

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Abstract

In this article we describe a long-term departmental change effort in one mathematics department. The change began with one instructor adopting the Extreme Apprenticeship instructional model. This modest shift served as the catalyst for a series of subsequent, systemic improvements. We believe that this innovation and the resultant change demonstrate how instructional change can serve as a catalyst for broader change, rather than a change that focuses solely on instruction. We use four frames from the literature on organizational development to characterize the changes that have occurred in this department. This in-depth case study describes the department's current culture and how it developed, and we suggest that this explanation could serve as a guide for other departments seeking change.

Keywords Institutional change · Organizational change · Departmental culture · Four frames · Mathematics education

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What is a hallway? A mere passageway between an office and a classroom? A place for casual conversation? In most departments in higher education the answers would be yes. However, the Department of Mathematics and Statistics at the University of Helsinki is different. Its hallways are a vibrant workspace of mathematical inquiry. Students work collaboratively in groups supported by faculty members and more advanced peers. The messages to students are clear: You are welcome here, this is a space for learning, and faculty members are here to support you. How did this situation come to be, how is it sustained, and how might other departments achieve such a positive, welcoming culture? These questions are the focus of this article.

Educational change is an important area of scholarship in STEM education. While this area has traditionally focused on scaling up instructional innovations (Henderson, Dancy, & Niewiadomska-Bugaj, 2012), more recent work has focused on systemic, department-level changes (e.g., American Association for the Advancement of Science, 2011; Association of American Colleges and Universities, 2014). Indeed, there is general consensus that scale-up approaches are unlikely to result in widespread change (Austin, 2011; Fairweather, 2008; Kezar, 2011). Scale-up approaches tend to be guided by weak, implicit theories of change (Borrego & Henderson, 2014); and empirical research shows that they are often ineffective (Henderson, Beach, & Finkelstein, 2011). Instead, approaches are needed that pay particular attention to culture as a part of the change process (Corbo, Reinholz, Dancy, Deetz, & Finkelstein, 2016; Reinholz & Apkarian, 2018).

We suggest that the explanation we provide in this article adds complexity to this research focus as we present a case of instructional change that served as a catalyst for deeper systemic changes. The instructional method in this case was Extreme Apprenticeship (Vihavainen, Paksula, & Luukkainen, 2011), but we believe that other instructional methods could serve a similar purpose. Thus, we argue that it is not a matter of positioning instructional changes *in contrast* to more holistic approaches to change, but rather that it is a matter of understanding the role of instructional changes *within* a broader change effort. We will describe the chain of changes in the departmental culture that occurred after the introduction of a new instructional method; our focus is not on the instructional method itself. To document the changes in this department we use four frames of organizational culture (Bolman & Deal, 2008; Reinholz & Apkarian, 2018).

After reviewing the literature on systemic change and introducing Extreme Apprenticeship, we provide *before* and *after* snapshots of the department to illustrate how extensive the changes are. These snapshots are followed by descriptions using the four frames, each outlining a trajectory of change for the department and a corresponding lesson learned in accord with each of the four frames. We then describe how the effort as a whole has changed perceptions of this department in the University.

Background

Educational Change

How educational change occurs and can be encouraged has become a major area of focus for the STEM education community. For example, Henderson, Beach, and Finkelstein (2011) reviewed an impressive 191 STEM change efforts undertaken between 1995 and 2008; and they concluded that narrow approaches (e.g., dissemination and top-down mandates), which were nearly 60% of the efforts reviewed, were “clearly not effective” (Henderson et al., 2011, p. 1). In a follow-up study the same researchers documented

how most of the change efforts were guided by overly simplistic and often implicit theories of change (Borrego & Henderson, 2014).

Many change efforts are aligned with the folk theory of change: “If you build it, they will come,” a theory that has an intuitive appeal. Given that educators want to serve their students well, one would assume that better teaching and learning strategies (e.g., active learning techniques) would be widely adopted as soon as they were developed (Freeman et al., 2014). However, this naïve interpretation of diffusion of innovations (Rogers, 2010) is not supported by empirical evidence (Austin, 2011; Fairweather, 2008; Kezar, 2011).

Lasting systemic change requires a more holistic approach that attends to culture (e.g., American Association for the Advancement of Science, 2011; Association of American Colleges and Universities, 2014). Broadly speaking, culture is an evolving set of practices and beliefs that are shared by a group and transmitted over time (Schein, 2010; Wenger, 1998). Because departments have relatively consistent policies, norms, disciplinary identities, and ways of interacting with students, they are relatively coherent units of culture (Lee, 2007; Lee, Hyman, & Luginbuhl, 2007). These features of a department make departmentally focused changes an attractive locus for achieving sustainable improvements.

A Model of Departmental Culture

For our consideration of departmental culture we use Bolman and Deal’s (2008) *four frames* model and operationalize the definition following Reinholz & Apkarian (2018): “Culture is a historical and evolving set of *structures* and *symbols* and the resulting *power* relationships between *people*” (p. 3).

These four components of culture – structures, symbols, power, and people – provide four ways of considering departmental culture. This culture is historical and evolving: change is inevitable, and to some extent the direction of change is rooted in the past. Nevertheless, intentional actions, such as the introduction of the Extreme Apprenticeship model in our focus department, can impact this trajectory of change. Furthermore, culture is experienced differently by each individual in a department. As explained below, while the changes in our focus department have been quite extensive, there remain individuals in the department who are only marginally impacted by them.

Structures consist of formal roles, responsibilities, practices, and routines. Such structures organize relationships by dictating who interacts with whom and how. Structures perform two central functions: they (1) help allocate work and (2) coordinate diverse efforts once work has been allocated. When organized effectively, structures can help a department fulfill its collective goals while still attending to individual differences. Structures constrain how individuals interact and can enhance or detract from their working relationships.

In this context *symbols* focus on beliefs and meaning making. Bolman and Deal (2008) used the term symbols to signify something much larger than inscriptions and disciplinary notation that are specific to a discipline such as mathematics. Rather, symbols refer to all of the artifacts, language, myths, and values that department members use to make sense of the world. Thus, meaning-making within a department is always mediated by the presence (or lack of) particular cultural symbols (e.g., beliefs about how students learn, deficit vs. asset perspectives about students, academic freedom). Rituals, stories, and key events in the history of a department may play an important role in how the present and future are understood.

Power mediates interactions through status, positioning, and political coalitions. Power relates to an individual’s ability to influence the circumstances of others (Keltner, Gruenfeld, &

Anderson, 2003). Thus, factions and coalitions often form within departments to support sometimes competing interests. In this sense, all social interactions are inherently political.

Departments are made up of *people* who have individual goals, needs, and identities. Thus, there is an issue of “fit” between individuals and the department. Does the department respond to individual needs? Do individuals help the department meet its collective goals? This frame also emphasizes interpersonal and group dynamics. Do individuals work together in a way that is productive for *all* persons in the cultural community? This frame draws attention to how different individuals may experience a departmental culture in different ways.

Before describing changes in the department using these four frames, we provide an overview of Extreme Apprenticeship. We intentionally keep the overview brief, as our purpose in this study is not to introduce a new teaching method, but rather to examine the effects it has had on the departmental culture and how these effects have influenced the sustainability of the effort.

Extreme Apprenticeship

Over recent decades the community of higher education has recognized the need to move away from traditional lecture-based teaching and to develop new instructional models that support students’ own activity, deep learning, and understanding (Baeten, Kyndt, Struyven, & Dochy, 2010). Examples of recently developed models are problem-based learning (Barrows, 1996), inquiry-based learning (Greeno, Collins, & Resnick, 1996), and flipped learning (Flipped Learning Network, 2014). Also new learning environments such as SCALE-UP (Beichner et al., 2007) and Math Emporium (Twigg, 2011) have been created for the same purpose.

One example of a new instructional model that supports student-centered teaching in large classes with hundreds of students is Extreme Apprenticeship (XA). XA promotes learning through apprenticeship (Collins, Brown, & Holum, 1991; Lave, 1996), with students learning skills by participating in activities that resemble professional activities (Rämö, Lahdenperä, & Häsä, 2018). Students report positive experiences with XA (Lahdenperä, Postareff, & Rämö, 2019), and passing rates in XA courses at the University of Helsinki have remained steady despite increased workload and conceptual demands expected of the students (Hautala, Romu, Rämö, & Vikberg, 2012; Rämö, Oinonen, & Vikberg, 2015).

An XA teaching team consists of a responsible teacher and a number of *tutors*. Any student who has successfully completed an XA course is eligible to serve as a tutor for the same course. The teaching team may also include support members who have taught with XA before, especially if the responsible teacher has no previous experience with the method.

The teaching team interacts with students in weekly learning cycles, with three components: working on tasks, submitting coursework, and lectures. Students work on tasks in a collaborative learning space located in the middle of the department. Tutors wear colorful safety vests to signify their role and work with students for multiple hours each day. Students submit weekly coursework and receive written feedback on selected tasks. They can revise their weekly coursework based on tutor feedback. Students complete tasks before attending lectures, which enables a flipped model of instruction. Lectures address students’ emergent conceptions and synthesize main ideas from the course, rather than simply delivering content. Each weekly learning cycle closes with more challenging tasks on the topic and introductory tasks for the next topic. As students complete their courses, many of them take on new roles (e.g., as tutors) and become more involved in the department’s community of mathematical

practice (Boaler & Greeno, 2000; Lave & Wenger, 1998). For a more detailed description of how XA is implemented in practice, see (Rämö et al., 2018).

The Study

Context and Personnel

The University of Helsinki is the largest university in Finland with over 30,000 students and 4,000 faculty members. It is a research-intensive university. University studies typically last five years with three years of Bachelor's studies and two years of Master's studies. Students declare a specific major when they enter the university, and their studies focus heavily on their chosen discipline from the beginning. There are no tuition fees for EU students, and Finnish students receive a grant from the state to assist in paying for their living costs.

The Department of Mathematics and Statistics at the University of Helsinki is the largest department in its field in Finland, with approximately 40 faculty members and 1,000 students majoring in mathematical sciences or mathematics education. Most faculty members are either full professors, assistant professors, or university lecturers. University lecturers have a permanent position entailing both teaching and research, but it is usually a position with more emphasis on teaching. The students in the department are selected mainly by their performance on the upper secondary school matriculation examination. Undergraduate courses in the department serve three primary audiences: mathematics students, pre-service teachers, and students in other STEM fields (e.g., computer science, physics, chemistry). Because the Bachelor's programmes are taught in Finnish, most students are of Finnish background. This population is relatively balanced in terms of gender.

Finnish students study calculus up to the concept of integral in upper secondary school, so students begin their university studies with proof-based courses *beyond* calculus (e.g., linear algebra). A typical introductory course load would include Introduction to University Mathematics (set notation and proofs), Linear Algebra and Matrices (linear algebra in finite-dimensional spaces) and Limits (real analysis with epsilon-delta-definitions).

Three authors of this article work in the Department of Mathematics and Statistics at the University of Helsinki, and they have been involved in the development of the XA method. They are also former students of the department. The first author was the responsible teacher for the first large scale XA course in the department. The third author has been using the XA method in his teaching since he obtained his Ph.D. in mathematics. The fourth author is studying the XA method as a part of her Ph.D. thesis in university mathematics education. The second author is an expert on departmental change and not affiliated with the department.

Data Review and Collection

The XA method has been the object of scholarly study since it was developed over seven years ago. For this reason, prior publications (e.g., Lahdenperä et al., 2019; Rämö et al., 2015) and the data collected provided a basis for understanding how the method had developed in the department over time. For example, we draw below from a questionnaire that was given to tutors for feedback. Our author team has also collected emails, artifacts, course schedules, and other relevant documents that highlight changes that have happened over time. In addition, we have performed member-checking with four relevant members of the department. We have

also cross-validated details of the spread of the method and its evolution over time using course websites and the tutor intranet. Below we describe our methodology in more depth.

Case Study Methodology, Explanation of the Case, and Four Frames

We used a case study approach in order to understand a “contemporary phenomenon in depth and within its real-life context” (Yin, 2009, p. 18). We present a single longitudinal case over seven years so that we can attend to the rich context in sufficient detail so as to allow us to describe changes in the department. Our construction of the case was guided by the following research question. *How did the introduction of a new instructional method serve as a catalyst for broader departmental changes?* We propose that it is possible for broader cultural changes to emerge from instructional improvements when department members pay sufficient attention to the interaction between instruction and the larger cultural context. We used constant comparative analysis (Krathwohl, 1998) to identify key events in the spread of XA and to understand how changes to the culture unfolded.

We also used Lincoln and Guba’s (Lincoln & Guba, 1985) *trustworthiness* framework—consisting of credibility, transferability, dependability, and confirmability—to guide our case construction. We built *credibility* for the case through finding patterns in the data and discussing and resolving conflicting explanations within our team. Our confidence in the validity of the case is a result of the experiences three of the four authors have had within the department and of the rigorous process of member checking. The second author, who is not affiliated with the department, provided the perspective of someone outside the department and contributed expertise in departmental change. For member checking, we shared this manuscript with the head of the department, two faculty members who are described in this article but were not involved in its preparation, and the former Master’s degree student who initially brought the XA method to the department. None of these individuals are authors on this article; their role was to provide experiences as privileged insiders in the department. Through this member-checking process, these four individuals confirmed the overall description below; and we have adjusted the manuscript where necessary.

To support *transferability*, we offer thick descriptions of the University of Helsinki and the focus department so that they can be situated within the appropriate international context. We outline the ways in which the department may be unique as compared to its peers so that readers can determine which aspects of our case may apply to their local context. Finally, we achieve *dependability* by carefully documenting our process and triangulating data sources. To check for consistencies in our description of the department, we shared an earlier draft of this article with four department members external to our authorial team and incorporated their feedback. In addition, we had lengthy discussions within our team of authors, three of whom are members of the department. This process also supported *confirmability* of the case, which requires a neutral perspective and avoidance of researcher bias. By incorporating feedback from member-checking and the anonymous reviewers of our manuscript, we sought to address this potential concern.

Our unit of analysis is the culture of the department as a whole. By considering the department as our unit, we focus on aspects of department culture that permeate the department, either because many department members are aware of them or because they have had a large impact on the department. Still, given that culture is not a single unified concept, we expect some other department members may view the circumstances slightly differently, given their unique perspectives.

We begin with a quick snapshot of the changes associated with XA. Then, we present further explanations within the context of the four frames to show how XA became much more than an instructional change.

The XA Revolution: Before and after

Before the XA revolution the department looked like most mathematics departments. Teaching and learning were driven primarily by a lecture-based, instructor-focused model. Teaching consisted of lectures, take-home assignments, and demonstration classes (breakout sessions). New topics were introduced in the lectures, students worked independently on assignments, and they discussed homework solutions in the demonstration classes. Demonstration classes were led by an assistant, who helped facilitate student presentations at the blackboard.

XA originated in the Department of Computer Science at the University of Helsinki (Vihavainen et al., 2011) and was initially adapted for mathematics by a single Master's student in spring 2011. Since then the method has continued to evolve (Hautala et al., 2012; Rämö et al., 2018) and proliferate within the department. By spring 2018 XA mathematics courses had been taught by 15 different responsible teachers: four doctoral students, five postdocs, four university lecturers, and two professors. The introduction of XA has promoted the idea of teaching and learning as a collaborative undertaking rather than a passive, solitary endeavour. XA has influenced the departmental culture in noticeable ways.

The most visible shift has been structural. Rather than working in isolated rooms for demonstration classes, students work collaboratively in the halls of the department. The result is that mathematics is “in the air”, and students have ample opportunities to receive support. This shift is also symbolic. Tutors roam the halls wearing bright and colored safety vests, a visible sign of XA. Given these visible signs and the widespread use of XA, it has become a part of the vocabulary of the department. Whether or not an instructor teaches using XA, they are aware of it.

The introduction of XA has also created new roles in the department. It has differentiated between tutors who are using XA and those who are not. It has created a new community for people in the department that provides professional development and collective engagement around a common goal. Tutors using XA are able to find personal satisfaction and growth in their work. Finally, XA has shifted the balance of power within the department. People have started to see teaching as a shared responsibility, and faculty members work to meet students where they are rather than asking the students to come to them. Starting with modest beginnings, XA is now sanctioned and embraced at the highest levels of the department, which has supported its growth.

Nevertheless, the adoption of XA has not been uniform; and other instructional methods have been developed and implemented in recent years. XA did not grow in a vacuum; it was heavily influenced by existing good practices, which helped it to take root in the department. Still, we argue that XA now has a clear presence in the department, and its proliferation has impacted the culture of the department in clear and meaningful ways.

Table 1 describes key elements of teaching that have appeared or changed focus with the coming of XA. They are arranged according to the four frames. Note, however, that XA has not transformed teaching as a whole, but rather added new elements that now exist alongside the traditional ones. Also, for clarity, we only describe here the difference between XA elements and the traditional standard form of teaching, while acknowledging that there are other innovative methods in use. Finally, many elements of XA fit in more than one of the four frames, depending on what is emphasized. For example, there is a *structure* in XA that has the tutors act as guides to the students. This changes the *power* balance because the tutor is no

Table 1 Summary of changes in the department by the four frames

Frame	Standard elements of departmental teaching	New elements added with extreme apprenticeship
Structures	<ul style="list-style-type: none"> • Classrooms • Assistants lead demonstration classes • Lecture(r)-based teaching 	<ul style="list-style-type: none"> • Collaborative, open workspace • Tutors guide students • Task-based teaching • Teaching teams • Pedagogical meetings for tutors
People	<ul style="list-style-type: none"> • Assistants work independently under lecturer's instructions • Assistants selected based on application • Students approach assistants 	<ul style="list-style-type: none"> • Teaching team works as a community consisting of several roles • Tutors hired via interview • Tutors approach students • Students encouraged to work together
Power	<ul style="list-style-type: none"> • Lecturer in charge of the course • Students come to faculty • Teacher assessment • Lecturer has freedom to work under given resources 	<ul style="list-style-type: none"> • Teaching team shares responsibility • Faculty come to students • Diverse forms of assessment, including self- and peer assessment • XA courses need extra resources which must be sanctified
Symbols	<ul style="list-style-type: none"> • Instructional developments tied to a specific course or lecturer • "Sage on the stage" 	<ul style="list-style-type: none"> • Extreme Apprenticeship "movement" with a core team of teachers, developers, and researchers • "Guide on the side" • Tutor vests • 3rd floor hallway

longer seen as an authority, but more as a figure offering support. The shift in power also changes the roles that *people* have in the learning community. Finally, tutors guiding students in their vests form a *symbol* of the XA method in the same way that traditional teaching was symbolized by the lecturer or an assistant leading the show in front of the class.

Within the framework of the four frames we now explain how XA has contributed to creating tangible changes in the department.

Frame 1 (Structures): Creating Visible Changes

Over time teaching has been understood as an individual, private act. Citing academic freedom (American Association of University Professors, 1940), faculty members generally believe that nobody else should tell them how to teach. For this reason, instructional changes are often individual, private changes that occur within the courses and classrooms of particular faculty members (Reinholz, Corbo, Bernstein, & Finkelstein, 2019). Thus, even though faculty members may be engaged in innovative practices, there are all too seldom structures that promote sharing such practices with other department members. In contrast, XA resulted in highly visible structural changes to the department, which were likely instrumental to its successful spread. The most visible structural change was the transformation of the main hallway of the department into a vibrant, collaborative workspace.

Before the introduction of XA, the department had offered homework help through "Laskupaja" (direct translation: calculation workshop). This was a classroom with tables and chairs and an assistant sitting in the front behind a desk. Students could come to the classroom to work with their peers and ask for help from the assistants. When the XA model was

launched, it first had a similar structure whereby students could get help from XA tutors. In contrast to Laskupaja help sessions, however, XA tutors walked around the classroom to talk to the students, rather than waiting for students to come to them. The XA sessions were probably popular with the students because the tutors approached the students actively and the sessions were tied to the teaching of a specific course. There was often not enough room for students to sit in the classroom. As a result, students began working in the main hallway of the department, near the XA classroom. Since tutors were already used to going to the students, they started doing so in the hallway, too. Soon, the hallway became an equally important working place for the tutors as the classroom.

At the same time, the original Laskupaja room had become quiet. Thus, it was decided that the Laskupaja assistants would also start working in the hallway and walk among the students. This form of general guidance was given a new name: “Ratkomo” (a place for solving). The Laskupaja assistants were renamed Ratkomo tutors, and they began to wear vests in a different colour from the XA tutors so as to signify their different role. Ratkomo tutors work across courses, whereas XA tutors are typically associated with particular courses.

This visible structure, working in the main hallway of the department, has transformed the atmosphere of the department (see Fig. 1). This structure – the physical space associated with learning in the hallway – represents more broadly the fact that the department has moved towards collaborative rather than solitary learning. The learning space is strongly associated with XA; in fact, most students start their mathematics studies with XA courses, and studying in the hallway learning space is a core component of those courses. The XA tutors contribute to a positive and vibrant feeling within this learning space as they encourage and actively engage with the students. After taking an XA course, many students continue to come to the learning space and work with the Ratkomo tutors. Because of the high visibility of the tutors working with students in the main hallway, XA has become a public instructional innovation, rather than simply a private act limited to a few classrooms.



Fig. 1 Students, tutors and faculty members in the learning space in the main hallway. (Photograph by Susanna Oksanen)

Frame 2 (Symbols): Branding the Efforts

Because of the way language can be understood as a *symbol* within the context of Bolman and Deal's explanation of the four frames (Bolman & Deal, 2008), the term *active learning* is a symbol that means a variety of teaching and learning techniques which involve students "doing the work" of learning, rather than just passively receiving information (Braun, Bremser, Duval, Lockwood, & White, 2017). However, one issue that arises with this umbrella term is that a number of instructors may be using active learning techniques; yet what each is doing in their classes may be quite different. Thus, it makes communicating instructional improvements more difficult because mathematics faculty members are not usually pedagogical experts; and they may not recognize nuanced differences between different teaching methods. We believe that the branding of teaching and learning improvement in the department as XA has allowed a variety of instructional improvements to be seen as part of a coherent system. Much like a business may develop a brand so that its products can easily be associated with one another, the brand of XA made it easier for the larger efforts to be associated together. In addition, it provides a convenient and common way to describe what has happened in the department, through a shift in discourse and visible symbols.

The English term "Extreme Apprenticeship" was coined in the Department of Computer Science at the University of Helsinki (Vihavainen et al., 2011). The name referred to Cognitive Apprenticeship (Collins et al., 1991) and a software development methodology called Extreme Programming. When the method was adapted to mathematics, it had no official Finnish name; and it was usually only referred to as "workshop" (in Finnish, "paja"). A more descriptive Finnish name was needed, but the Finnish equivalent for apprentice ("oppipoika") could not be used because it translates roughly to "learning boy" and hence was not gender neutral. Instead, a related word, "kisälli" (journeyman, a worker who has already completed an apprenticeship but is not yet licensed to have their own workshop as a master) was chosen. The Finnish name for the method became "tehostettu kisällioppiminen" where "tehostettu" (boosted) refers to the fact that the method can be used for teaching large courses and "oppiminen" means learning.

The fact that there is now a specific term for the teaching method makes communication easier. One can talk about "kisällikurssi" (XA course), and immediately most people in the department will have an idea of what kind of teaching is meant. For example, a faculty member can be asked if they would like to teach an XA course. Also, advanced students can tell less advanced students what they can expect from the XA courses. The tutors that teach for the XA courses are called "kisälliohjaaja" (a person who guides students in an XA course), and students can apply for kisälliohjaaja jobs knowing what is expected from them.

The emergence of XA has even changed terminology in the traditional teaching of the department. The Finnish title for an assistant has traditionally been "laskuharjoitustenpitäjä" (person who leads a computational exercise session). The last part "pitäjä" of this compound word refers to leading, supervising, or simply having. In the XA method, on the other hand, the tutors are called "kisälliohjaaja". The part "ohjaaja" refers to guiding or directing, implying that the tutor actively guides the student instead of merely supervising an exercise session. A while after the XA method was implemented, the title of the traditional assistants, laskuharjoitustenpitäjä, was changed to "laskuharjoitusohjaaja" to emphasize that the assistants *guide* students. These linguistic symbols help staff and students talk about a different teaching method, and they may contribute subtly to shifting of attitudes about teaching.

There are also the visible symbols associated with XA as we have already explained. These symbols originated from structural decisions, but they have since outgrown the structural frame; and we believe that they contribute to the branding. One of these visible symbols is the main hallway of the department, which is in the middle of the department; and students as well as professors walk through it several times during the day. The hallway is also used for different kinds of meetings. Phrases like “let’s meet in the hallway” or “she was just now in the hallway” are common parlance. The other visible symbol, the colorful vests, have also come to symbolize student-centered guidance and student-faculty interaction.

Frame 3 (People): Building a Strong Community

The changes that have occurred in the department have required members of the department to develop new instructional skills. This includes permanent faculty as well as students involved in teaching. Concerted efforts support tutors and provide them with a positive work experience.

Every semester there is an open announcement for tutor and assistant positions. Students are selected to be tutors based on their academic performance and an interview focusing on their pedagogical views. It is important to build a positive community when using XA because the responsible teacher and the tutors form a team that works and plans teaching together. At the beginning of the semester, the teaching team members participate in a professional development session; and during the course they have weekly pedagogically oriented meetings, which are conversational and inclusive. The tutors’ and responsible teachers’ viewpoints have equal value, and new ideas raised in the meetings develop the XA method further. There are also more informal meetings. The tutors are requested to organize a social event for themselves so that they get to know each other. At the end of each semester, there is a retrospective for the teaching team to talk about how the semester went and make plans for the future. Recently, the traditional assistants have also been included in the initial professional development sessions and retrospectives, which we believe influences their professional development as well.

New tutors are brought into the XA community each year. Experienced tutors take on the role of “senior tutor” and have additional responsibilities and receive more pay. They ensure silent knowledge transfer by offering support to the less experienced junior tutors and new responsible teachers. Because there are more applicants than positions, some tutors move on each year. They may be hired to a more traditional teaching position through which they can then spread the student-centered teaching methods they have learned.

Tutors have a central role in the teaching team of a course and also in the departmental community by building a bridge between students and faculty. Being a tutor is a popular job among students, and more students apply for tutor positions than assistant positions. Tutors’ views were surveyed as a part of a Master’s project supervised by one of the authors (Salmijärvi, 2017). Their answers in the survey indicated that they enjoyed their work. When asked what they enjoyed the most, one tutor gave the following answer (translated to English): “That I can be of help in the moment of insight and learning. The guidance is best when a student does not need the tutor for anything other than listening or asking questions [...]” Another tutor wrote (translated to English), “Being a tutor was on the whole even more fun than I had thought. For this very reason, the past semester was the most rewarding time I have spent in the university (so far).”

Frame 4 (Power): Early Wins and Visible Progress

Like most systemic changes, the improvements associated with XA have required monetary support. As XA has spread, individuals involved with the effort have made their progress visible, early and often, which is a key strategy for supporting change (Kotter, 1996). They have given presentations at University events and scientific conferences and published articles (e.g. Hautala et al., 2012; Rämö et al., 2015). This has resulted in continued support from key faculty members.

XA had humble origins in the department. In spring 2011 a Master's student received permission to teach a section of a large course using XA. Because the results were promising, he got permission for the method to be used on a larger scale in a 400-student linear algebra class. The responsible teacher was a young part-time teacher, and the head of department was a co-teacher. The academic affairs officers of the department helped in planning and administering the course. (In Finland, an academic affairs officer is a person who plans and organizes teaching at the departmental level by, for example, scheduling teaching and finding teachers for courses.) Extra monetary resources for this pilot course were granted by the dean of the Faculty of Science.

In retrospect, it was crucial that the head of department supported this pilot effort, even though the method was not very cost-effective in the beginning. During the first trials the teaching arrangements were modified according to the teaching team's experience and student feedback, and costs were reduced. Also, collaboration between faculty members and administrators was central, because the academic affairs officers had a lot of power in the department. One of the academic affairs officers soon assumed an especially active role in pushing the XA method to new courses. A conference paper of the teaching experiment presented at an international audience demonstrated the promise of XA to key stakeholders (Hautala et al., 2012). XA continues to be an active area of research in the department.

Over time some faculty members have become advocates for the XA method. In 2015 a successful mathematics researcher was asked to be the responsible teacher of an XA course. He saw the value of the method and talked very positively about it to other faculty members. He even helped another professor in using some ideas of XA in his teaching. In 2017 a full professor was asked to teach an XA course. The professor had started a significant educational development in the department in 2000 and was vice director of the department. He gave an inspired address about his experience at a departmental event.

These two faculty members – a respected researcher and a senior faculty member involved in promoting instructional change – enjoy considerable standing in the department. They are also members of University committees. In these roles they have endorsed XA and referred to it as a positive example of educational improvement in the department. By so doing they raise their own status as members of such an innovative department, and they bring more recognition and power to the developers of XA. The same is true of the head of department, who has mentioned how pleased he was after hearing the directors of other departments talking about the new kind of teaching in mathematics. The XA method and development of teaching in general have often appeared in his talks as important innovations in the department.

The positive role of the head of the department has also been important for the fiscal support of the of the XA method. For example, discussing funding for XA and other teaching innovations has become easier because the head of the department seems convinced that the XA team is doing a good job. As another example, major reforms have taken place in the University as well as severe cuts in funding for teaching. As an expensive-looking method, XA has been under threat several times; but it has been easier for the developers to protect the method because key faculty members have publicly supported the method.

The Paradisum

The above explanations describe departmental change in the context of four frames. However, these frames are not disjointed aspects of an effort; they reinforce one another. For instance, the symbols associated with XA help create a climate and culture that meaningfully reinforce the way XA structures are used. Similarly, the early successes of XA have resulted in support from the department, which has provided resources to build a stronger community, which has reinforced successes, and so the evolution continues.

A telling example of the changes, which could hardly be recounted without all of the four frames, is how XA appeared in the student magazine of the University of Helsinki. The magazine is a nationally regarded publication which, apart from student matters, also discusses cultural and societal topics. The editor of the magazine visited the department in 2013 and was impressed by the atmosphere and what she saw. She wrote a short editorial in which she admired the support given to the students as well as the community spirit evident in students and faculty working together (Kaarenoja, 2013). She went as far as advocating to change the name of the building from “Exactum” to “Paradisum”.

The editor highlighted *structures* in the department, including the physical environment with students actively working on “tables in the hallway”. She recognized that XA is not just the product of the efforts of individual *people*; rather it is the product of a sustained community effort. Important persons from other departments mentioned the editorial to the head of the department, which brought *power* and sanction to the effort. Finally, the word Paradisum itself has become a new linguistic *symbol* in the department, referring to the physical learning space and to the good relationship between the faculty and students.

Conclusion

In this article we have described a change process in the teaching culture of a mathematics department using the model of four frames – structures, symbols, power, and people. We believe that this explanation of organizational change contributes to the literature in several ways. First, it shows how an instructional change can lead to broader changes. Second, it describes a rather novel use of departmental space, the hallway. Third, it explicates a long-term effort using the four frames model and offers experiences that could be of benefit to those working on other change efforts. As a retrospective case study, we have been limited in reporting on change that has already happened, rather than watching change as it unfolds. Nevertheless, there are key insights from this study that we believe can be applied to future change efforts – for ourselves and others.

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