Exploring the Adoption, Spread, and Sustainability of an Informal STEAM Learning Innovation in Schools

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Abstract: This symposium brings together different studies on the adoption and sustainability of FUSE Studios, an alternative STEAM learning infrastructure. Since its launch, FUSE has been adapted successfully in 136 different school-based implementations operating across 18 different states and two countries (USA and Finland). Yet, despite being tailored to each context by local actors, FUSE has largely managed to preserve the integrity of implementation as educational innovation. Each contribution explores a point in the lifecycle of a FUSE adoption and describes local adaptations of the approach in the US and in Finland. In addition to addressing the critical question of how new educational innovations are adopted and sustained, this symposium provides perspectives on how to balance adaptability to local contexts and the integrity (rather than fidelity) of implementation.

Keywords: STEAM; scale-up; organizational learning; Actor-Network Theory

Session summary

A common goal in the learning sciences is the conceptualization and design of learning environments that improve learners' opportunities and contexts for learning. It is also a goal to implement more broadly those carefully tended pilot innovations that achieve these objectives. While the diffusion of innovations has been studied and conceptualized in other fields (e.g., Greenhalgh, et al., 2004; Rogers, 2003), far less is known about how educational innovations travel between contexts and what factors aid or hamper wider implementation. The existing literature makes two key points. First, while initial adoptions of an innovation can be made with significant support by an implementation team or partnership, moving and 'scaling', beyond a local, carefully tended context can be difficult and is often unsuccessful (Clarke, 2008; Hubbard, Mehan, & Stein, 2006; McNeil, 2002). Second, the *adaptability* of innovations to new contexts is an important contributing factor in their wider implementation and spread (e.g., Coburn, 2003; Cole, 2005; Penuel et al., 2011). Designing for adaptability is, however, tricky and poses a two-horned dilemma. On the one hand, while insisting on strict adherence to 'fidelity of implementation' (O'Donnell, 2008) may preserve the organization and elements of an intervention's original design, it also stifles educators' abilities to tailor an innovation to local contexts. That may weaken the innovation's fit to the local context and reduce the ownership local educators experience with regard to the innovation. On the other hand, allowing for local adaptation risks educators inadvertently undermining what made the original innovation successful, producing 'lethal mutations' (Brown, 1992) or depriving the implementation of 'integrity' to its original core principles and practices (LeMahieu, 2011). While the idea of designing for adaptability is common, research on *adapting in practice* is still rare.

This symposium brings together four different case studies of how a particular educational innovation called FUSE Studios has been and is continuing to be adopted and adapted in 137 different school-based implementations operating across 18 different U.S. states and two countries: the United States and Finland. (For an overview video about FUSE, visit www.fusestudio.net). When implemented with integrity of implementation—as prior research shows it can be at the scale of a large Midwestern public school district (Stevens et al., 2016)—FUSE represents a significant departure from typical classroom practice. Participating in FUSE involves students exploring a collection of about 30 STEAM (science, technology, engineering, arts/design, and math) challenge sequences that level up like video games. In-school implementation models vary, but a common approach is for a FUSE Studio to meet for two or three periods during a school week. Examples of challenge activities include programming a robot to perform actions ("How to Train Your Robot") building your dream home in a digital 3D environment ("Dream Home"), and a range of challenges that involve making 2D digital designs that students then 3D print (e.g. "Print my Ride" and "Eye Candy"). FUSE classrooms differ from traditional academic subject matter classrooms most fundamentally in the fact that students choose among the challenges, and the principle of choice extends to who they work with, how long they work on challenges, and whether they continue with challenges (or further levels within challenge sequences). The core commitment to choice is rooted in the goal of seeking to help students find, cultivate, and deepen their own STEAM-based interests. An outcome of the interest-based pathways that students navigate through FUSE because of choice is that peer-to-peer teaching and learning is the norm in FUSE classrooms, with teachers playing more facilitative roles. As well, in FUSE classrooms there is no testing, and grades are deemphasized or eliminated. Our prior field research on FUSE has shown common features of FUSE classrooms to include: (1) students devising and inhabiting diverse "learning arrangements" to do their work; (2) students developing and sharing "relative expertise" that emerges as they work on challenges of their own interest and choice; and (3) students pushing through frustration and learning from 'failure', since 'failure' is not penalized as it is in typical classrooms but treated as "just another try" (e.g., Ramey, 2017; Stevens et al., 2016). While our prior research has shown that these features are shared across implementations in schools within one large U.S. school district, the question we pursue here is whether and how these common, distinctive features of FUSE Studios are more broadly sustainable as it is introduced into new, more distant contexts.

The focus on a single educational innovation (FUSE Studios) for this symposium is strategic, because it allows for an analysis of how the same 'package' (Becker, 1972) is interpreted and implemented under different conditions, thereby making those conditions visible and showing the range of possibilities for an innovation, in relation to particular features of local contexts. Here, we follow the broad logic of studies of the Fifth Dimension, which employed a garden metaphor to ask about the relationship between 'seeds' (in this case, the FUSE suite of tools, materials, and recommended practices) and the local ecological conditions in which the seeds grow, thrive, mutate, wither, or die (Cole, 2009).

Extending the ecological metaphor, this symposium considers implementation in terms of a life-cycle, studying how the implementation of FUSE at different phases of its life-cycle. For the purposes of this symposium, we conceptualize implementation in terms of three potential phases: *getting in*, *getting rooted*, and *spread*. Getting in refers to how a school (or collection of schools) decides to implement and adapt their basic infrastructure to accommodate the innovation. Getting rooted refers to the phase in which local educators, working in partnership with the university-based FUSE team, work out the details of an implementation, adapting it and, at the same time, adapting local practices, to stabilize it within the local school context. Finally, *spread* refers to both the intentional and emergent ways in which FUSE has moved from two afterschool implementations in 2013 to 136 implementations spanning the US and two countries.

Each of the four contributions to this symposium represents a case study of implementation, at different phases in the life-cycle, and each contribution provides an analysis of how FUSE is interpreted, adopted, or adapted. The contextual conditions in which FUSE has been introduced vary considerably. The first contribution traces how FUSE evolved from an afterschool implementation to a stable, in-school implementation in collaboration with a large Midwestern school district. The second contribution focuses on a later stage in the spread of FUSE, in which FUSE is being adopted across a wide variety of geographically-distant schools. This case study is based on nine new schools implementing FUSE in distinct ways that are representative of patterns in the larger dataset. The third contribution focuses on the first year of FUSE implementation into the very different institutional and cultural contexts of public elementary schools in Helsinki, Finland, where FUSE is currently implemented in six schools. This analysis is based on the first two schools to implement FUSE in 2016. The final contribution is a case study of how FUSE is being implemented in one public school classroom that represents a different but growing species of FUSE adoption; while early adoptions of FUSE in public schools have largely been as stand-alone classes within a traditional school infrastructure, the growing interest in STEAM and makerspaces has led to FUSE being integrated into classes and spaces oriented toward these goals. This case study explores this species of implementation. Taken together, these cases allow us to explore adaptations of FUSE as processes of *mutual appropriation* (Downing-Wilson, Lecusay, & Cole, 2011). By focusing on a single educational innovation in different contexts, we will offer both concepts and specific empirical findings to contribute to questions of how learning scientists can bring their design offerings to wider audiences with integrity of implementation (LeMahieu, 2011). This 90-minute symposium will include an eight-minute introduction, fourteen-minute presentations, a ten-minute synthesis from the discussant, and fifteen minutes for audience questions.

Adaptation begets adoption: How an unusual educational innovation became part of the regular school day in a large Midwestern school district

Jaakko Hilppö and Reed Stevens

In this paper, we present a study of the adoption and adaption of an innovative educational program called FUSE Studios, in a large Midwestern school district. Our paper focuses on a time period during which the implementation of the program expanded significantly and became a stable part of all of the 27 schools in the district. In specific, we highlight two key moments in this process. Given that FUSE Studios can be characterized as a highly unusual program, in the context of conventional school practices (Stevens et al, 2016), our study of its implementation represents an information-rich case study on the spread of educational innovations. Moreover, our paper provides one of the first studies that looks in detail at how an innovative educational program gets in, gets rooted, and spreads within a school district.

In our study, we conceptualize the adoption and adaption process of FUSE Studios from an Actor-Network Theory (ANT) perspective (Latour, 2005; Fenwick & Edwards, 2010). In other words, we conceptualize FUSE Studios as an actor, a particular assemblage of human and non-human actors, that through various moments of 'translation', gets incorporated into the standing and relatively stable actor-network of the traditional public school day. In ANT, an actor's agency is based not in its inherent qualities but from the network of associations in which the actor comes to be embedded; actor-networks have effects, like stability or change. Yet, which actors come to be part of any network cannot be determined in advance, but rather, need be uncovered by researchers by tracing the associations within the network. Prior work in ANT has been able to show that, most often, the scope of the actor-network that constitutes, for example, a successful pedagogical program, is far more extensive and heterogeneous than it might at first appear (e.g., Nespor, 2002).

The data for our study come from open-ended interviews (Patton, 2002) with key personnel working on both sides of the FUSE Studios research-practice partnership; this includes the FUSE program coordinator, its two creators/founders and district coordinators and administrators. In addition, we have used documents produced by both parties, such as public school board records, local newspaper articles, blog posts, email exchanges and promotional material to understand the adoption and adaptation process. In our analysis we used both the interviews, as well as the existing documentation, to create a retrospective reconstruction of the implementation process and its different phases (e.g. Miettinen, 1999).

During the time period analyzed for this paper (Spring 2013 - Summer 2016) the implementation of FUSE in the district grew from reaching approximately 380 students in five schools to reaching 4000 students in 27 schools, through four different implementation models. Our analysis highlights two significant moments of translation in this process to illustrate the complexity of adoption, thus illustrating the value of ANT's sensitivity to heterogeneity: (1) when FUSE Studios was adopted and adapted as an in-school exploration class; and (2) when FUSE Studios was further adapted into a district-wide engineering and design class. Furthermore, our analysis shows how a heterogeneous set of different actors, like late busses, equity goals, state standards, 3D-printed objects, parents, and a large industrial company took part in how FUSE Studios was incorporated as part of the students' educational experiences in the district. For example, after the initial implementation, to respond to the positive feedback on the program and to achieve the district's equity goals, the district administrators looked into afterschool clubs, as a way to provide the FUSE experience to all interested 5th and 6th graders. However, due to the lack of late busses, the district could not transport students to and from the five schools that had FUSE Studios. This, along with the new state science standards that the administration needed to comply with, led the administration to contact the FUSE design team and eventually to design a new FUSE Studios implementation with them. This new version was then introduced to all of the schools in the district.

Moreover, our analysis shows that the process also produced new actors that were able to connect, translate, and stabilize the various constraints and pressures directed toward the extending network of FUSE Studios in the district. For example, as part of moving FUSE Studios into the school day, the district created a new administrative position, a STEM Coach, and delegated the daily management of the implementation to that position. At the same time a new version of FUSE Studios, as an in-school exploration class, was created, through collaboration with the FUSE Studios design team and the district administration. Both the new STEM coach and the new implementation of FUSE Studios played consequential roles later in the implementation process.

In sum, our study contributes to the still-thin scholarship that investigates educational change processes from an actor-network perspective (Fenwick & Edwards, 2010). As such, our paper adds to the current literature on educational change by illuminating the complex, heterogeneous arrangements involved in enacting change and countering overly simplistic, often top-down, narratives of how educational innovations are implemented.

Removing the blindfolds and finding the elephant: From diverse anticipations to convergent experiences of an educational innovation

Kay Ramey, Jaakko Hilppö, and Reed Stevens

Because FUSE requires a technological and pedagogical infrastructure that is quite different from traditional school infrastructure, it faces particularly intense challenges related to scale-up and sustainability (Hargreaves, 2010; Rogers, 2003). There is a risk that as FUSE Studios gets adopted into new schools, it may adapt too much to local contexts, losing its core design components. Conversely, it may not adapt enough, making it unsustainable. Therefore, in coordinating with schools implementing FUSE, we have attempted to balance adaptability to local constraints (Clarke, 2008; Hubbard et al., 2006; McNeil, 2002; Penuel et al., 2011) with integrity (rather than fidelity) of implementation (LeMahieu, 2011). In other words, rather than mandating strict replication, we provide training and support to foster implementations that align with both core design principles of FUSE Studios and local needs and circumstances.

This approach to implementation provides an opportunity to understand the work that stakeholders put into adapting and sustaining educational innovations. It also provides us with an opportunity to understand the sociomaterial conditions that lead to successful scale-up. Accordingly, this study examines FUSE as a boundary object (Star & Greisemer, 1989) and examines, via an Actor Network Theory (ANT) perspective (Latour, 2005), how the associations between the ideas, practices, and artifacts that constitute this object change over time, in local contexts, and how they shape implementation.

We draw on data from 57 schools implementing FUSE as a new program during one academic year. Many of these schools are high-need schools, with large underrepresented minority and low socioeconomic status populations, that received FUSE as a grant. Data collected from these schools includes: (1) written applications submitted by schools to fund and implement FUSE; (2) recordings of phone conversations between schools and our team; (3) observations and video recordings of facilitator training sessions; (4) interviews with students, facilitators, and administrators; (5) observations and video recordings of students doing FUSE; and (6) social media and community discussion board postings related to FUSE implementation. Here we focus on analysis of data from 14 focal schools implementing FUSE in distinct ways that are representative of patterns in the larger dataset.

Analyses of schools' applications for FUSE showed 24 perceived qualities of FUSE that stakeholders associated with, as reasons for pursuing FUSE for their school. Among these, the most common were "STEM", "STEAM", "career preparation", "equity", "21st century skills", "problem-based learning", "collaborative learning", and "personalized learning". During facilitator trainings, additional associations were made, including associations with specific components of the technical infrastructure of FUSE, such as the 3D printers provided to each school as part of the program. Later analysis of interviews and community discussion board posts showed variation in the ways in which FUSE was integrated into the school day and the sociotechnical networks that ended up comprising FUSE in different local contexts. For example, while some schools experienced difficulty setting up the necessary technological infrastructure or finding physical space to run the program, others had well-equipped makerspaces before beginning the program and merely lacked curriculum for those spaces. Similarly, while some schools ran "pure FUSE" a totally choice-based, ungraded STEAM exploration experience, others felt pressure to align FUSE activities with standards (e.g., NGSS, ISTE, Common Core) and to find ways to assess and attach grades to student progress during their FUSE experience.

However, despite differences in initial conceptualizations of FUSE and implementation models, our analyses suggest that the program maintains high integrity of implementation across diverse contexts. For example, despite the wide variety of associations with FUSE listed in schools' applications for the program, in interviews with facilitators, administrators, and students after they'd begun FUSE, discourse converged around a description of a common set of student and facilitator experiences. We consistently heard stories of students helping each other and collaborating on challenges, pushing through frustration and learning from failure, discovering new capacities and interests, and demonstrating greater engagement and fewer behavioral problems in FUSE than in other classes, qualities of FUSE we've identified in our previous research (Ramey, 2017; Stevens et al., 2016).

Based on these analyses, we argue that the adaptable nature of FUSE is what allows it to both get in and thrive in a variety of different contexts. In other words, the program serves as a boundary object, simultaneously allowing different stakeholders to form a variety of different associations with the program but also carrying with it a set of core associations that are resilient to changes in local ecology. This finding challenges conventional wisdom that tested educational innovations can or should be imported into new contexts as is, without adaptation and with what has been called "fidelity of implementation". In our analysis, adapting is not a threat but a means for sustainable implementation, not only in FUSE but in scaling up other technology-rich STEM learning environments in diverse school contexts.

FUSE as a "nested" phenomenon: How an innovative intervention fares within an existing context of innovation

Peter Meyerhoff

The interaction of a design-based research project with its context(s) of implementation represents an ongoing theoretical and empirical challenge in the learning sciences (Penuel, Cole, & O'Neill, 2016). Each context has a particular social, material, and institutional history that constrains and guides any educational intervention. On one hand, researchers seek to design for a consistent experience at scale: once a program has been iteratively developed and improved, the goal is to make it resilient to changes in context as new sites are added (O'Neill, 2016). At the same time, the differences among contexts may constitute precisely the phenomenon of interest in a design research program (Cole & Packer, 2016). FUSE, an interest-driven, STEAM learning environment (Stevens et al., 2016), has grown rapidly, and early research has suggested that it maintains its essential core across implementation contexts (DiGiacomo, Van Horne, & Penuel, 2017). An important possible difference has emerged, however. During early implementations, no activities other than FUSE were allowed in the room. But as the program has grown, some schools have brought FUSE in as an available option within established classes that *already* provide some form of interest-driven, choice-based activity structure. This raises a possible scenario that may be new to the literature on implementation, which normally conceptualizes innovative programs as phenomena foreign to their environment.

How does an innovation like FUSE fare when it enters a context of implementation in which its new practices are already explicitly well-aligned? The answer is not self-evident. Perhaps local actors, seeing nothing new in the innovation, will reject it altogether. Alternatively, it could be that since people in the environment are well-prepared for the new ideas, they might enthusiastically embrace them and let go of what came before. To investigate this question, I examine one case of a *nested* implementation: the installation of FUSE within the Tech21 elective at Eagle Lake Junior High. I conducted 6 months of observations in Tech21, spoke daily with the teacher, interviewed 7 school and district leaders, and examined internal district memoranda. I watched students work and talked with them about their experiences. I made regular counts as to how many students were engaged in each activity at any given time, and frequently asked students why they had chosen one activity over another. In what follows, I show that FUSE ended up in a stable, parallel co-existence with the existing Tech21 program.

In 2015, before district leaders learned about FUSE, Eagle Lake remodeled the school's old science room into a "STEAM Lab," which they called a "collaborative makerspace", and created a new class, Tech21. A memo from the district's technology director to the superintendent and the school board declared that Tech21 reflected a vision for "choice driven activities" that "engage students in STEAM topics, while fostering the development of important 21st century skills." Eagle Lake had filled the STEAM Lab with an assortment of the latest devices and tools--Spheros, Makey Makeys, Cubelets, FlyBrix. and many others. Students had laptops with access to online tools and activities such as TinkerCAD, Unity, Minecraft, Kerbal Space Program, and CodeCombat. By the end of the year, however, administrators grew concerned about what they believed was a lack of what they called "progression" in Tech21. Searching for more structure, the technology director found FUSE and purchased the program for the 2016-17 school year, handing it to the Tech21 teacher, Mr. J, to implement.

The existing technical infrastructure—mobile devices with students well-accustomed to their use—made it easy for students to get started in FUSE. Moreover, the open-plan layout of the STEAM Lab encouraged the movement and collaboration that is characteristic of student work in FUSE. Mr J provided moderate encouragement to students to choose FUSE challenges. However, other Tech21 activities—Minecraft, Kerbal Space Program, and FlyBrix in particular—attracted significant participation. In each Tech21 class, activity in FUSE eventually stabilized to account for about one-third to one-half of activity. Students mainly either stayed in or out of the FUSE environment.

At the same time, students' engagement, as evidenced by their focus on and attention to their projects and their active collaboration with other students, remained broadly consistent across FUSE or non-FUSE projects. Most students entered Tech21 and went immediately to their work and remained involved through the end of the period; a few students even came in during their lunch period to continue working on their projects. Whether it was constructing a working airplane out of FlyBrix and cardboard, writing a program to solve a Rubik's Cube, or designing a "dream home" in FUSE, students in Tech21 worked over extended periods on complex, elaborate creative and technical projects. The one snag that occurred affected participants in FUSE and non-FUSE activities equally: Eagle Lake struggled to find a way to assess and grade participation in Tech21.

In sum, FUSE came into Eagle Lake as an innovation located inside another innovation. It occupied a parallel position within the STEAM Lab alongside the existing activities in Tech21 and found a core base of participants. This research suggests that a nested intervention may achieve successful integrity of implementation and complement, rather than dislodge, the new practices already in place.

"Please, no hanging around, return back to your own works" - Teachers and students negotiating social and cultural rules for their engagement and learning in FUSE

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Despite a proliferation of implementation efforts of novel learning environments to schools, resources are seldom directed into longer-term follow-ups of these efforts. In response to this research gap, we investigate the first year of adaptation of FUSE Studios in two Finnish schools. Building on cultural historical theorizing and ethnographic logic of inquiry, in this study we focus on how students and teachers negotiate social and cultural norms and rules for their engagement and learning in FUSE, a novel technological infrastructure designed to support choice-based STEAM learning based on students' interests (Stevens, et al., 2016). In specific, we are interested in potential tensions that can emerge when existing social and cultural norms of schools meet with those rules and norms that participants attach and negotiate for their engagement and learning in FUSE.

As no educational innovation functions in a vacuum, in this study we investigate the axiology FUSE embodies, the experiences it generates, and the actions it makes possible and forecloses, both for students and their teachers, within the cultural context of Finnish schooling. Our study holds that it is important to examine possible disjunctures, resistances, and tensions between different sets of norms and rules, when educational changes are implemented, because these can provide important information on how educational innovations are locally adapted and what features aid or hamper their effectiveness (see also Rajala & Sannino, 2015; Kennedy, 2005). To this end, in this study we ask: How do students and teachers negotiate social and cultural rules for their engagement and learning in FUSE Studios?; and What tensions emerge, and what are their consequences, when existing social and cultural norms of the school interact with those established for FUSE?

The ethnographically (Marcus, 1998) collected, empirical data for our study are derived from two Finnish public schools with children aged 7 to 12 years old (School 1: 251 students and 16 teachers, School 2: 535 students and 28 teachers). FUSE was introduced to these schools by the city, to support the implementation of the new Finnish core curriculum in practice. The teachers of the schools were provided with a 2-day training workshop on FUSE, combined with online tutoring from the developers.

The empirical data are comprised of video-records and field notes, of students' and teachers' social activity in FUSE, and student and teacher interviews, collected intermittently over one academic year. Sociolinguistic and ethnographic discourse analysis (Gee & Green, 1998) and interaction analysis (Jordan & Henderson, 1995) have guided the analyses. We analyzed moment-by-moment interactions and critical events in which tensions emerged with regards to the rules and norms for engagement and students' learning practices in FUSE.

Our findings indicate that the forms of engagement and learning available to the students and their teachers in FUSE resonated in many ways with the Finnish core curriculum, which emphasizes connecting informal and formal learning and recognizing student expertise and local knowledge in solving multidisciplinary and authentic challenges. For instance, in their interactions in FUSE, the students actively applied and validated their previous experiences and knowledge, embedded in their social ecologies, in and out of school, in order to solve STEAM challenges of their preference. The students' developing expertise and interests were also actively recognized by their teachers and peers in joint activities, as students were officially nominated as expert tutors of specific STEAM challenges. Here, the traditional teacher-student roles were transformed, as expertise became more relative. At an institutional level, the recognition of students' expertise resulted in transformed social and cultural structures, as students were called upon from their regular class to the FUSE Studio to act as experts for a challenge that no teacher or other student could solve.

The findings also illustrate tensions. Not all students found interest in the STEAM challenges and the teachers struggled in motivating them. Also, some teachers resisted the freedom of student choice - an important FUSE design principle - to the result that they decided to close down some FUSE challenges, as they wanted to have more control over the content of the students' work. Some forms of student engagement that characterize

FUSE were also found to result in tensions and restrictions. For instance, not all teachers appreciated the students' "hanging around" in the FUSE Studios while the students followed and observed their peers' work on challenges. These attitudes reflected the traditional norm of individual accountability for school work. Likewise, the forms of assessment built into FUSE (or lack thereof) created tensions as the teachers wanted to evaluate the students' learning progressions in FUSE. For this reason, some teachers created additional portfolio and/or reflection tasks for their students. The interview data suggests that many of the teachers considered only formalized learning with a separate evaluation component as legitimately addressing the students' learning.

Altogether, our study contributes to understanding local adaptation processes of FUSE into the everyday life of schools, with the actors' point of view at the center. In this adaptation process, the adopters also actively changed the meaning of the practice. Hence, implementation goes along with transformation (Rogers, 2003, Kajamaa & Schulz, 2017). Our study shows how the teachers and students did not respond passively to FUSE but that their specific needs, objectives, sense-making and experiences importantly shaped their engagement and learning practices, leading to unexpected and creative solutions, which at times deviated from and contradicted with the original intentions and plans set forth for FUSE. The participants became not only adopters of the existing resources (i.e. the prefixed FUSE tasks), but actively drew from their previous learning experiences, resisted, initiated change, and challenged and shaped the implementation process. On this basis, we suggest that implementation of educational innovations needs to be viewed as a continuous process in which design, implementation and learning are intertwined.

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