An Additive Innovation-Based Faculty Development Program: Methods for Case Study Research

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Introduction

With calls to revolutionize engineering education by linking theory and practice [1], faculty members who can not only take pedagogical risks [2], but share their ideas within a community of practice [3], become a necessity. This paper discusses methods and progress toward formally defining case studies and iteratively building a logic model to capture the outcomes of faculty participation in a professional development program based on the additive innovation cycle [2].

The purpose of this paper is to describe a methodological approach for designing and preparing case study research in the context of a faculty development program based on the additive innovation cycle. Additive innovation is a mindset that promotes collaboration through openness and sharing within a community of practice [2]. The semester-long faculty development program engaged faculty in activities centered around the additive innovation framework, with an embedded research goal of understanding the outcomes of faculty participation in such a program [3]. The program was developed as part of a research project that is funded by the National Science Foundation "Revolutionizing Engineering and Computer Science Departments" (RED) program [4] at Arizona State University (ASU). The RED project at ASU, entitled, "Instigating a Revolution of Additive Innovation: An Education Ecosystem of Making and Risk Taking" (EEC-1519339), is answering the call for revolution by empowering faculty to realize a mindset of pedagogical risk-taking and additive innovation in their classrooms [4].

The implemented, additive innovation-based intervention focused on promoting the sharing, scaling, and sustainability of pedagogical risk-taking within a community of 15 faculty participants with teaching-focused appointments. Participants came from different disciplines within an engineering school and with teaching experiences ranging from 0-20 years [3]. The overarching research question for this study was: *How are instructors in an undergraduate engineering program impacted (positively and negatively) by participation in an additive innovation cycle focused on pedagogy?*

Participants were interviewed at the beginning, middle, and end of their participation in the program. Analysis of the interview transcripts has focused on changes in participants' practices, attitudes, and intentions related to pedagogical risk-taking as they engaged in the additive innovation cycle, Our preliminary findings show that participants valued being part of a community of practice that is open to engaging with colleagues and sharing their experiences in a risk-taking endeavor. The participants' developed and implemented pedagogical innovation was also an opportunity for them to gain comfort with risk-taking behavior and trying new things. These findings are specific to the context of openness and sharing within the Pedagogical Ninjas program; however, understanding the underlying mechanisms that empower faculty members' mindset in pedagogical risk-taking is important because of the potential for transferability to other contexts.

This work is intended to help demonstrate to engineering education researchers how a case study method approach can be used to study complex phenomena with multiple variables of interest (in

this case, the process of using professional development to initiate a faculty change initiative). The paper also shares how a case study research design can benefit from utilization of a theoretical framework (e.g., the additive innovation cycle) and from the collection of multiple sources of evidence to help triangulate findings. We describe the set of decisions made throughout the analysis planning stage to identify patterns of behavior among cases (faculty members), including why decisions were made, how they were implemented, and to what ends. The process to build each case is described, and examples are shared.

Background on the Pedagogical Ninjas Program

Pedagogical Ninjas Program

The Pedagogical Ninjas program was designed to combine faculty development around pedagogical risk-taking with the dissemination of ideas through an additive innovation cycle [4]. Inspiration for the program came from previous efforts to create and sustain faculty-led learning communities [5], that are willing to take risks [4] in pedagogical transformation [6, 7, 8]. An additive innovation cycle (Figure 1) is a community-driven process wherein participants engage each other in the following four steps: (1) *becoming inspired* by the local community and instructor peers, (2) *sharing and learning* about pedagogical ideas and artifacts, (3) *iterating* on one's own pedagogical ideas and artifacts, and (4) *sharing* their pedagogical innovations back to the community. The cycle stems from observations of the Maker community [2] and emphasizes the sharing of ideas for innovation and the empowerment of faculty as agents for change.

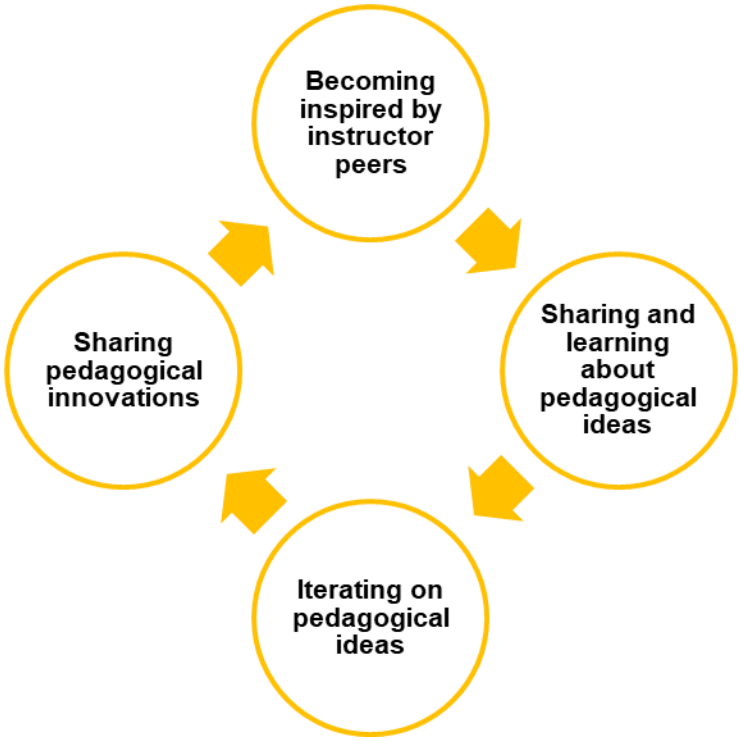

Figure 1. An additive innovation cycle [4].

An overview of the program and its activities is shown in Table 1, with further details of the program discussed in a previous paper [3]. The disconnect between research and practice is

widely acknowledged, and thus, program activities were intertwined with a parallel, intensive cycle of research design and data collection [9] during the implementation of the program between May and December of 2018.

Table 1. Schedule of activities as presented during the kickoff meeting.

Additive Innovation Phase	*Month*	*Activities*	*Attendance*
Inspiring Community	August	Kickoff meeting	*required*
		Lightning round presentations	*required*
Sharing & Learning	September	Teaching and pedagogy workshops	*attend 2 of 4 sessions*
Iterating on Designs	October	Teaching hackathon sessions	*attend 1 of 2 sessions*
	November	Community building happy hours	*optional (2 events)*
Sharing Innovations	December	REDtalks story crafting workshop	*required*

Research questions

The research team is focused on answering the following research question and sub-questions:

1) How are instructors in an undergraduate engineering program *impacted (positively and negatively) by participation* in an additive innovation cycle focused on pedagogy?
    a. How are *pedagogical risk taking and other teaching related outcomes* (e.g., self-efficacy in instruction) influenced by participation in an additive innovation cycle focused on pedagogy?
    b. How do *additional outcomes (e.g., sense of belonging to academic community, job satisfaction, etc.)* among individual instructors arise from participating in an additive innovation cycle focused on pedagogy?
    c. How are these outcomes associated *with particular phases of the additive innovation cycle?*

Data Sources

A cohort of 15 non-tenure track instructors were engaged in a professional development program based on the additive innovation cycle. Participants were selected to create a coherent community of uniform rank and shared perspective on the importance of teaching. Data were collected from each participant in multiple forms: teaching artifacts they created, surveys, reflective interviews, and videos of stories about the experience. Details about each stage of the additive innovation cycle, including collected data, are provided in [3].

Overview of case study research

Characteristics and advantages of case study research

Case study research has been used ubiquitously in psychology [9], sociology [10], political science [11], social work [12], business [13], and community planning [14]. Case study research

is suitable when research questions ask about the "how" and "why" of a real-life phenomenon under study, when the researcher has little control over the outcomes of the events under study [15], and when *the boundary between the phenomenon and context is blurred* [16]. The case study method of inquiry also aims to investigate multiple variables of interest collectively, which differs from an experimental research design where a phenomenon is separated from its context in order to observe a controlled set of variables [15]. Analysis of the Pedagogical Ninjas program lends itself well to a case study approach, because the faculty development activities are intertwined with our effort to understand the influence of risk-taking behavior and other outcomes (e.g., sense of belonging to an academic community, job satisfaction, etc.) [17, 18].

Case study research also relies on multiple sources of data as evidence for triangulation. Yin [15] discussed six different types of data that can be used as evidence in case studies: documentation, archival records, direct observations, participant observations, physical artifacts and interviews. Multiple sources of data were collected in the context of the Pedagogical Ninjas program, including the artifacts that participants created (such as presentations describing former and planned teaching innovations), surveys, reflective interviews, and a crafted story about their experience at the end of the program.

A third characteristic of case study research is that it relies on previous theoretical frameworks to guide research design, providing a blueprint for the study [10]. The additive innovation cycle (see Figure 1) acts as the theoretical framework for the research design in the context of the Pedagogical Ninjas program.

Disadvantages of case study research

One of the critiques to case study research has been the lack of systematic procedures. However, Yin explains that the lack of existing systematic procedure is due largely to the lack of existing texts on the topic, in addition to the tendency of bias to promote certain findings and conclusions in some case studies [15]. Like any research, case study research without rigor in the design and clarity of execution s suffers from lack of quality. Another critique of case study research has been the lack of basis for generalization, but Yin points out that case studies are generalizable to propositions, rather than populations, in the same way that experiments are. Lastly, case study research has been criticized as involving long write-ups with too many results [19] because they often get confused with ethnography and participant-observation studies [17, 18], but this need not necessarily be the case.

Logic model development

The analysis of case study evidence can follow different systematic methods, including pattern matching, explanation building, time-series analysis, cross-case synthesis and developing logic models [15]. Logic model development follows a process of tracing the outcomes produced by interventions (i.e., events) [27]. This process logic models overlaps with pattern matching in that empirical observations are matched with theoretical propositions used prior to research design; however, logic models emphasize the sequencing of stages in analyzing the data [10]. Because the Pedagogical Ninjas program followed a series of steps, we chose logic model development as a deliberate way to study the effect of, and interaction between, events over time. An archetype of a logic model is provided in Figure 2. Enumerated circles represent interventions, and boxes

represent stages. Interventions are considered to impact and build on each other temporally [10]. Each stage can thus be both the outcome of one intervention and an input for the following intervention. Outcomes can be immediate, intermediate, or ultimate, depending on the time scale on which it is observed.

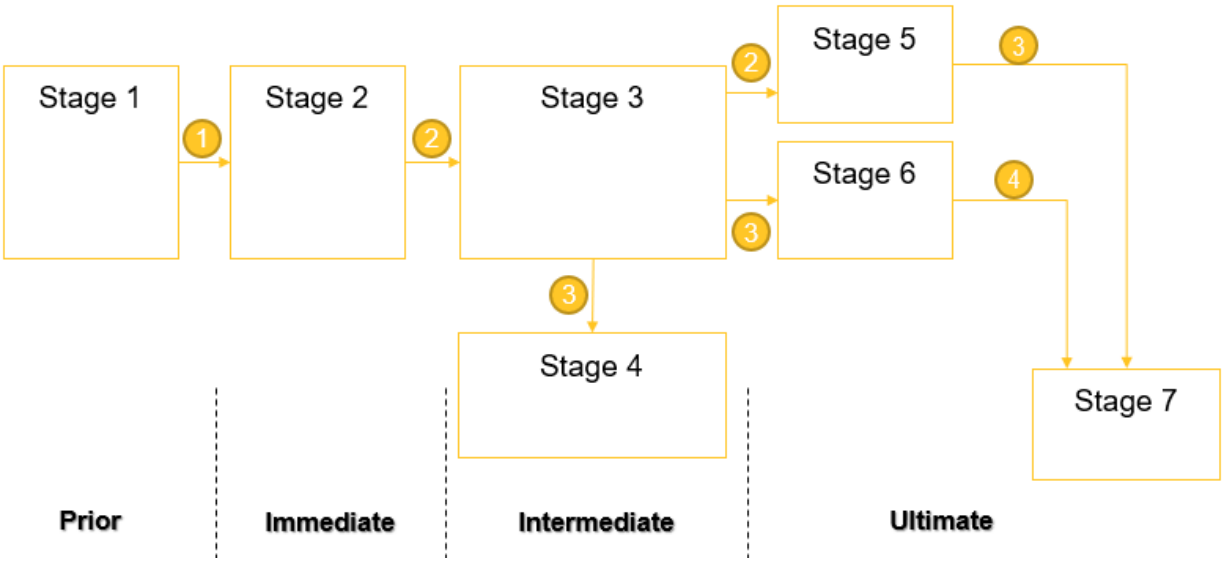

Figure 2. An archetype of a logic model.

Outcomes in the context of our analysis are defined from the perspective of a faculty participant, as opposed to a general "program" outcome, since we are interested in understanding how individual participants evolved over the course of the Pedagogical Ninjas program. Outcomes at strategic times in the program are identified from the deliberate coding of interviews that took place proximate to each of those times. Outcomes can be psychological, such as *confidence*, *change in perspective*, *a sense of accomplishment*, or *willingness to try new things*, or they can be more action-oriented, such as the *formulation of a new idea* (immediate), *the building of community with peers* (intermediate), or the *successful implementation of an innovation during the program* (ultimate). Further, while interventions refer to the four overarching, defined phases of the additive innovation cycle in our study, we further identify the particular mechanisms or activities within each of these broad phases that actually led to these outcomes (e.g., exposure to a specific learning tool, rather than just attending a teaching and pedagogy workshop).

Yin emphasizes that a logic model should be defined in advance of data collection. Collected data is then evaluated against the model to see whether the data empirically supports or refutes the model [10]. Rival explanations of the logic model enrich the understanding of the model [20]. We built our initial logic model by organizing our empirical data according to our proposed additive innovation model, i.e., by outlining how a faculty member navigates through the program and is inspired to design, implement, and share outcomes from a pedagogical intervention that they perceived as risky. Refinement of this model is ongoing, as we capture the finer details of faculty members' participation in the additive innovation cycle and its impact on their practices, attitudes, and intentions related to pedagogical risk-taking. We are also interested in understanding whether the impact is different for different groups of faculty participants.

Data collection: Understanding the data structure

Interview protocols

The primary source of data in this study is a set of three interviews conducted at strategic points during the Pedagogical Ninjas program with participants: after the Lightning Round event at the beginning of the program, after the Teaching Hackathon event in the middle of the program, and after the REDtalks Story Crafting Workshop at the end of the program (see Table 1). Interviews were reflective in nature, following a semi-structured protocol and taking approximately 30-60 minutes to complete. They were audio recorded and transcribed verbatim. Sample questions are included in Table 2. Questions asked during the first interview centered on prior teaching experiences before joining the program, followed by experiences with the program so far (including the Lightning Round event), as well as elaboration on takeaways up to that point. Questions asked during the second interview centered on the teaching hackathon experience and how participants used what they had gained in the teaching and pedagogy workshops and other aspects of the program for planning their innovation. Questions asked during the third interview centered on outcomes of the implementation of their innovation, their experience during the REDtalks Story Crafting Workshop, and overall reflections on the program. Data were anonymized by giving a pseudonym to each participant. Data anonymization was useful for creating an analytic distance [21] between the researchers and the data, especially given that program events and data collection were intertwined, creating a close relationship between researchers and participants.

Table 2. Sample interview questions from the three interviews conducted with participants.

Sample interview questions from the *first* interview: ● Before joining the Poly Pedagogical Ninjas, how would you describe your teaching approach? ● Where do you think other faculty would put you put you on a spectrum from more common or traditional to novel? ● Before joining the Poly Pedagogical Ninjas, was there ever a time, when you wanted to make a change in your teaching, but didn't? Tell me about that.
Sample interview questions from the *second* interview: ● How would you describe your overall experience at the Hackathon? Did you work with anyone else during the Hackathon? ● Do you consider what you are planning to do as risky? Why? ● Which experiences have encouraged you to innovate on your teaching the most?
Sample interview questions from the *third* interview: ● How do you think implementation of your innovation went? ● How much do you think the idea for your innovation has evolved from the beginning of the semester to the end? ● Now that the semester has come to an end, how do you think your teaching philosophy has changed as a result of participating in the Ninjas program?

Exploring potential cases

A multiple case study structure (shown in Figure 3) was used to analyze the interviews based on early observations, from interviews and survey responses, that the outcomes associated with events within the Pedagogical Ninjas program might differ based on teaching experience. Participants in the program had varying levels of teaching experience, ranging from 0 to 20 years [3] Multiple cases have been used in previous case study research to compare different cases, with each case having its own context and with samples purposefully selected *a priori* to make the comparison (e.g., [22, 23, 24]).

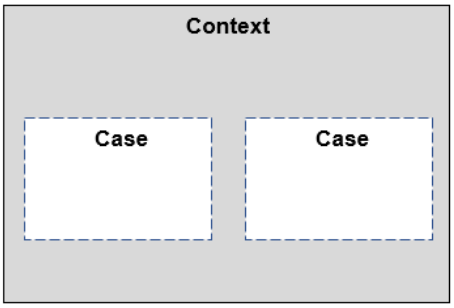

Figure 3. Case study research design: Multiple cases, same context.

Exploratory analysis of data

Exploratory analysis of data has gone through three major phases, discussed below. A unique contribution of this research has been the integration of thematic analysis, as grounded in qualitative research traditions, with logic model development, as used in case study research. Following the traditional approach to multiple case study research of simply testing the collected data against the hypothesized logic models was insufficient to answer our research questions. The large data size, concurrent nature of event implementation and data collection, emergent nature of cases in the analysis, and need to capture fine details within the interviews meant that the research also required combining aspects of qualitative data analysis with case study research. We iteratively arrived to a process where we first analyzed the interviews for codes and themes related to the outcomes of faculty participants in the Pedagogical Ninjas program. These codes are currently being checked for inter-rater reliability between analysts. Development of the logical model using individual participants will commence once a codebook is finalized. The result has been a rigorous and novel approach to data analysis.

Phase 1: Organizing data around research questions and interviews questions

The data set for analysis consisted of three interviews each for all fifteen participants, for a total of 45 interviews. The large data size prompted the research team to first map the questions in the interview protocol to our research questions (Table 3), and then group together participants' responses to the same interview questions (Table 4). The outcome of this phase was better understanding of the variation in responses between participants to each question, by providing a compilation of the data in one place.

Table 3. Sample mapping between research questions and interview protocol questions.

Research question	
1	**How are instructors in an undergraduate engineering program <u>impacted (positively and negatively) by participation</u> in an additive innovation cycle focused on pedagogy?**
Sample interview questions	*Before joining the Pedagogical Ninjas, how would you describe your teaching approach?* *Do you think you'd be doing this innovation if you weren't currently part of the Ninjas program? Why?*
1a	**How are <u>pedagogical risk taking and other teaching related outcomes</u> (e.g., self-efficacy in instruction) influenced by participation in an additive innovation cycle focused on pedagogy?**
Sample interview questions	*Do you consider what you are planning to do as risky?* *How will you know if your innovation is successful?*
1b	**How do <u>additional outcomes</u> (e.g., sense of belonging to my academic community, job satisfaction, etc.) among individual instructors arise from participation in an additive innovation cycle focused on pedagogy?**
Sample interview questions	*Has the program changed the conversations you have with other faculty? How/why?* *How does Pedagogical Ninjas compare to other professional development experiences you've had*
1c	**How are these outcomes associated with <u>particular phases of the additive innovation cycle?</u>**
Sample interview questions	*How would you describe your overall experience at the Hackathon?* *How easy or difficult was it to develop a story about your innovation?*

Table 4. Sample mapping between interview questions and participant responses.

1c. How are these outcomes associated with <u>particular phases of the additive innovation cycle?</u>	
Tell me about how Poly Pedagogical Ninjas is going for you so far.	
Alexander	Well, I think the ninja program probably for me, the biggest value is that it's really pretty rare for me to **talk about teaching with my colleagues**, you know, especially in this college. Usually, if I do something I go to [Campus 1] or I go to [Campus 2] for training. But to actually work with people in the programs next door and, you know, across the way and that kind of thing it's really for me, it's a first. And so, **there's lots of little tidbits I'm picking up just informally through conversations**, you know, before, during, or after an event that are really helpful. And I like the spirit and sort of the camaraderie of the group. It seems to be a really good group of people who are willing to be open, and cooperative, and helpful with advice, and I like that.
Betty	It's going really well. I've really enjoyed doing it, and **I feel more confident about what I do or how I speak about what I do**.

Phase 2: Creating preliminary logic models

Our next phase of analysis involved taking a closer look at one participant at a time and creating a draft logic model from their set of three interviews. The purpose of this phase was (1) to develop a process for creating and generalizing a logic model across participants; and (2) to understand the variations in the logic models and use these variations to begin to identify multiple different cases. We started with two participants whose responses were concise in order to facilitate the process; these participants had limited and extensive teaching experience, respectively. We attempted to create a logic model following the additive innovation cycle for each participant. The logic model for one of these participants (Alexander, with 12 years of teaching experience) is shown in Figure 4; note that we present this figure simply as an example of how we thought through the organizational structure for our results, rather than to depict actual results.

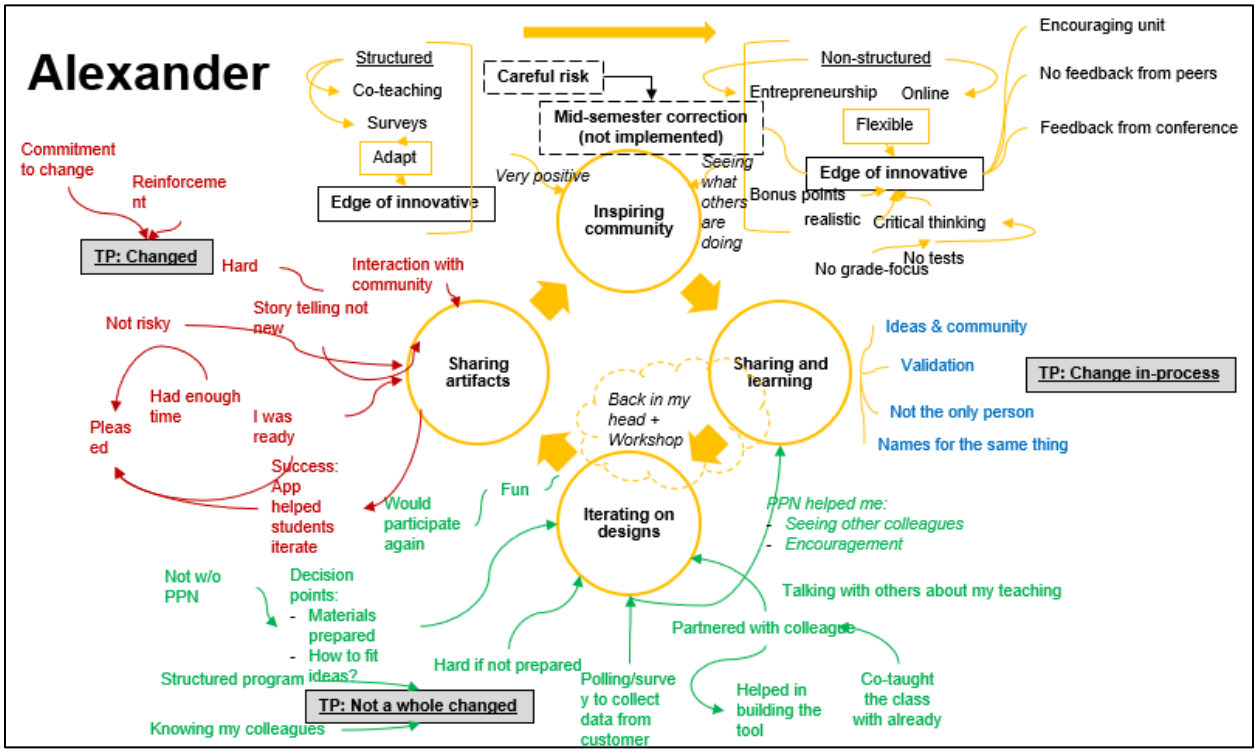

Figure 4. Sample draft logic model following the additive innovation cycle for Alexander. (Note: We include this figure just as an example of one organizational strategy and not as an effort to demonstrate actual results.)

We realized during the creation of these models that it would be helpful to have a "summary" that captures the essence of the outcomes reported by the participant in each interview. We also wanted to create richer logic models, following the archetype in Figure 2, to capture immediate, intermediate, and ultimate outcomes of faculty participation in the Pedagogical Ninjas program [10]. Figures 5 and 6 show snapshots of the interview summary and revised logic model format for another participant (Betty, with 7 years of teaching experience). Notably, all three of our graphical methods (Figures 4-6) for organizing the data were based on the participants' own language, which was simultaneously informative and overwhelming. This way of analyzing the data also made comparison across participants difficult. We concluded based on these

experiences that we needed a more robust and reliable process for creating the summaries and logic models for each participant.

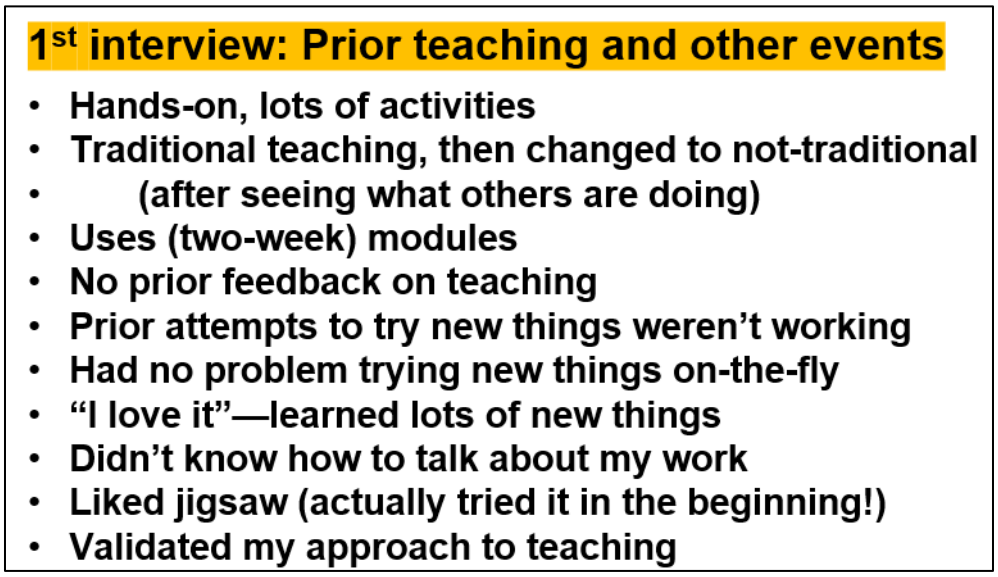

Figure 5. *Sample summary of the first interview with Betty*

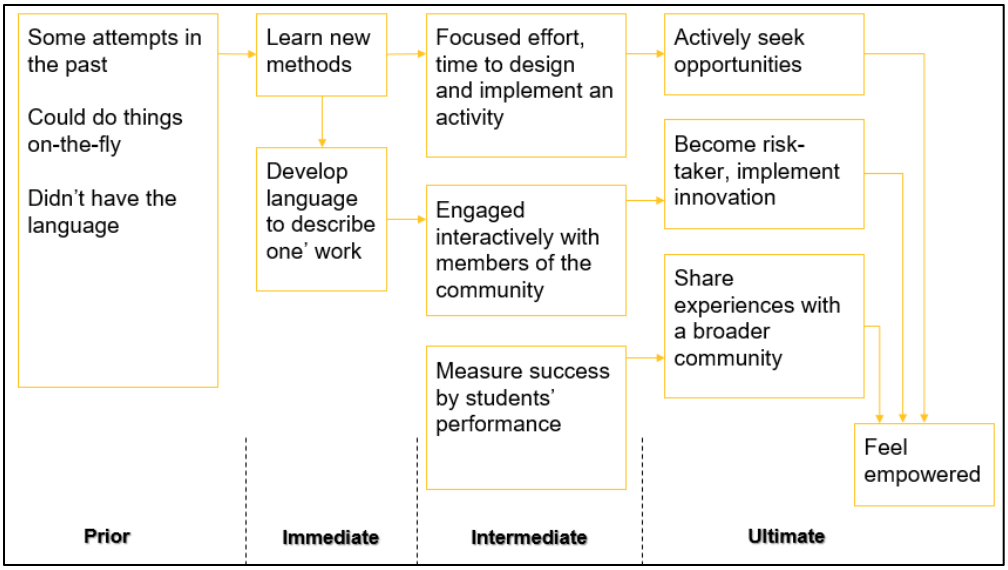

Figure 6. Sample draft of a logic model based on a summary for Betty, capturing immediate, intermediate and ultimate outcomes.

Phase 3: Creating summary profiles for participants

A template was generated for use in creating a summary profile for each participant following our insights from Phase 2 (see Table 5). The template provides a high-level profile of the participant, describes the participant's implemented innovation (in their own words), and then provides summaries for the (1) outcomes, (2) changes in teaching philosophy, and (3) changes in risk-taking behavior noted from their participation in the Pedagogical Ninjas program. Each outcome is being given a brief description paired with evidence cited from the interview

transcripts, as exemplified in Figure 7. Outcomes are being identified by one researcher and checked for intercoder reliability by another researcher to establish a codebook that standardizes outcomes (what they are, what program activity they are associated with, and the exact mechanism through which the outcome developed) across all interviews.

Table 5. Elements of the template for profile summaries for participants.

(A) Description of participant background (based on interviews) 1. Teaching experience 2. Professional development (around teaching) experience 3. Industry/other experience 4. Current program 5. Other relevant details
(B) Description of the implemented innovation (based on both interviews and REDTalks)
(C) Summary of outcomes (based on interviews) *Guiding question 1:* *What outcomes occurred due to participation in PN (e.g., positive implementation in a course, motivation to implement a new change, confidence, sense of belonging, and others), and what specific part of PN influenced the development of these outcomes (e.g., interpersonal interactions with PN community members, exposure to new ideas from a workshop/presentation, time to plan during hackathon, etc.)?*
(D) Summary of changes in teaching philosophy (based on interviews) *Guiding question 2:* *What changes in your teaching philosophy occurred due to participation in PN?*
(E) Summary of changes in risk-taking behavior (based on interviews) *Guiding question 3:* *What changes in your self-described pedagogical risk-taking behaviors occurred due to participation in PN?*

Outcome: Implementing a new activity from the teaching workshops (other than planned innovation)

Betty described how she already implemented the jig-saw activity and other activities in her classes after she was introduced to it in one of the teaching workshops:

- I1 (p. 6): "Yeah, jigsaw? So, I did that one. I used that one in class. I used it for not so much learning about things but like finding a design example that was find a design example, that was good […]" **[Workshop] [event resulted in implementing a new activity after being introduced to it]**

Figure 7. Example of an outcome in the summary for Betty. Note the outcome description, the evidence provided, and the mechanism through which the outcome emerged.

Future work: Creating and formalizing the codebook

The three phases of the exploratory analysis of the data resulted in the need to code the collected data to standardize outcomes and mechanisms. An ongoing coding process where members of the research teams are checking codes for inter-rater reliability is currently underway. Codes are being identified, given definitions, and applied independently by the coders. Ultimately, the emergent outcomes, as well as the links between outcomes and mechanisms, will be used to create and compare logic models for two cases of faculty: a group with limited teaching experience, and a group with extensive experience. The findings will shed light on the impact of both the additive innovation cycle and the creation of a community of practice focused on sharing pedagogical innovations on the risk-taking behavior of faculty from different backgrounds.

Conclusions

This paper described the need for, and the process of, developing a novel methodological approach for designing and preparing case study research in an engineering education context. The approach combines features of thematic analysis from qualitative research with logic model building from case study research. The advantage of this new approach is that, as opposed to relying on hypothetical models that come from life experiences, it produces more robust, reliable logic models that are based on substantiated evidence from a large set of data. The newly developed approach will be used to develop and compare logic models of multiple cases of faculty with varying levels of teaching experience who were engaged in an additive innovation cycle to implement a pedagogical innovation within one semester. The ultimate findings of this case study research will enhance our understanding of effective ways for linking theory and practice in pedagogical transformation.

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