STUDENT IMPLEMENTATION EXPERIENCES IN BLENDED LEARNING: A PHENOMENOGRAPHIC AND NARRATIVE ANALYSIS TO INFORM PEDAGOGICAL INNOVATION

by

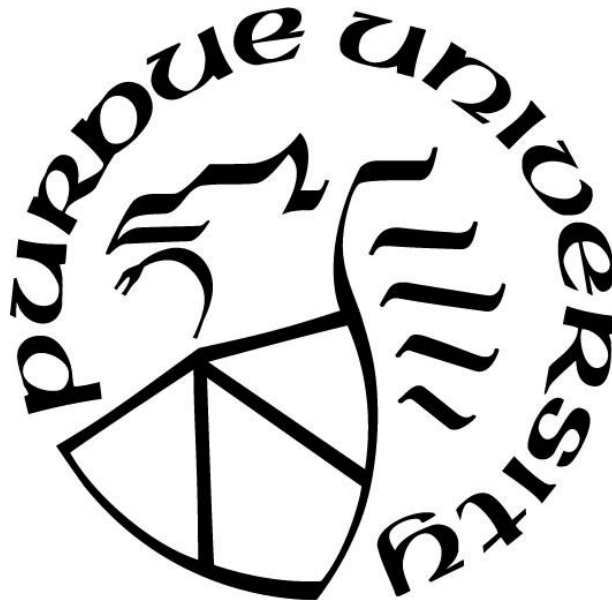**David A. Evenhouse**

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Dedicated to Tessa Rose; lover of stories and constant source of inspiration.

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ABSTRACT

In this dissertation, I argue that there is value in treating students as implementors during processes of educational innovation. I lay the groundwork for this argument through a review of literature comparing best practices in the implementation of innovations in higher education with best practices from active learning, blended learning, and collaborative learning research. This is followed by a phenomenographic and narrative analysis: a deliberate combination of phenomenography and narrative analysis methods for the interpretation of data and representation of findings, leveraging the strengths of each approach to account for the other's shortcomings. The result of this work is an outcome space containing a hierarchical framework typical of phenomenography describing the various ways in which the participating students experienced implementation within the context of a blended learning environment called *Freeform*. The presentation of this framework is followed by a series of constructed narratives which contextualize how the hierarchical framework may be evidenced in student experiences of implementation in higher education.

The hierarchical framework contains six categories of description: Circumstantial Non-Adoptive, Circumstantial Adoptive, Preferential Non-Adoptive, Preferential Adoptive, Adaptive, and Transformative. Proceeding from Circumstantial Non-Adoptive and Circumstantial Adoptive to Transformative, each subsequent category of the model characterizes implementation experiences that are increasingly impacted by students' own self-awareness of their personal learning needs and subsequent self-directed learning behavior. This represents a departure from previous implementation research in engineering education for a number of reasons. First, it demonstrates that there is value in considering students' roles as implementors of educational innovations, rather than tacitly treating them as subjects to be implemented upon. Second, the use of the word "circumstantial" intentionally acknowledges that the external (environmental) factors that influence implementation can be distinct to individual implementors while remaining contextual in nature. Third, it demonstrates that the processes of implementation which students undergo can lead to concrete changes in learning behavior that extend beyond the scope of the implementation itself.

Narrative analysis is used to develop a series of narratives that embody the implementation experiences communicated by student participants. These narratives are constructed using

disparate ideas, reflections, and tales from a variety of participants, emplotting representative characters within constructed stories in a way that retains the student perspective without adhering too closely to any individual participant's reported experience. This approach serves two goals: to encourage readers to reflect on how the categories of the hierarchical framework can be demonstrated in students' experiences, and to reinforce the fact that individual students can exhibit implementation experiences and behaviors that are characteristic of multiple categories of the framework simultaneously. It is important to remember that the categories included in the framework are not meant to characterize students themselves, but rather to characterize their interactions with specific pedagogical innovations.

The study concludes by interpreting these results in light of literature on implementation and change, proposing new models and making suggestions to faculty to inform the future implementation of educational innovations. Faculty are encouraged to treat students as implementors, and to exercise best practices from implementation literature when employing educational innovations in the classroom. This includes adopting practices that inform, empower, and listen to students, intentionally employing strategies that allow students to exercise their own agency by understanding and utilizing innovations effectively. Prescribing specific innovations and forcing students to use them can be detrimental, but so can freely releasing innovations into the learning environment without preparing students in advance and scaffolding their resource-usage behaviors. Instructors and researchers alike are encouraged to consider implementation from a new perspective, students as implementors, and faculty as facilitators of change.

INTRODUCTION

Researchers in Engineering Education have long called for broader dissemination and application of research based educational innovations in undergraduate engineering education (Borrego et al., 2013). From major journal publications (Besterfield-Sacre et al., 2014; Jesiek, Borrego, & Beddoes, 2010) to policy pieces (Jamieson & Lohmann, 2012), Engineering Education Research (EER) works have highlighted how few of such educational innovations have been effectively translated into widespread practice. Examining the spread of some key innovations has shown that their propagation across higher education can be slow to the point of stagnation. These innovations can take decades to be translated into general practice as part of undergraduate engineering instruction (Litzinger & Lattuca, 2014).

This need for an increased translation of educational research into instructional practice has in turn inspired a greater academic interest in the topics of implementation and organizational change, both in the context of EER and in the broader STEM education research community (Henderson, Beach, & Finkelstein, 2011). Many writers have tried to explain why institutions of higher education appear so resistant to pedagogical change, and sought to more accurately model the process of implementation in undergraduate STEM education (Cohen & Ball, 2007; Henderson, Finkelstein, & Beach, 2010). Researchers have found that simply taking an innovation and directly applying it to a new classroom or institution is often unsuccessful (Litzinger & Lattuca, 2014), as such prescribed innovations are frequently met with stiff resistance among the impacted faculty (Dancy & Henderson, 2008). In addition, forced replication of innovations between contexts can result in negative effects on the performance and experience of both students and instructors (Dede, Honan, & Peters, 2005).

With these findings in mind, researchers in EER have emphasized the important role that contextual differences play in determining the success of educational innovation. Instructors are often particularly aware of context, and expect to be able to adjust and adapt instructional innovations to fit the unique concerns and affordances of their own environment. Many factors can change when moving from one institution to another including the technology available, the needs of the student population, and the pedagogical preferences of the instructors themselves (Cohen & Ball, 2007; Henderson & Dancy, 2006; Dancy & Henderson, 2008). Strong personal conceptions of learning theory and effective teaching practice combined with a long history of educational

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experience not only change how faculty perceive educational innovations to fit their classrooms and students (Englund, Olofsson, & Price, 2017), but also shape how they adapt those innovations for instructional use (Henderson, Beach, & Finkelstein, 2011). Thus, implementors play a critical role in determining not only the success of pedagogical innovations, but also the form that these innovations ultimately take in the academic contexts to which they are applied.

Introducing Students as Implementors

However, despite this acknowledgement of the important role individual users, or implementors, play in the implementation of innovations in EER literature, the role of the "implementor" has been almost exclusively reserved for instructors. Faculty are regularly represented as agents of change in educational innovation and are placed at the center of discussions related instructional change in undergraduate instruction (For example, see: Liu, Geerthuis, & Grainger, 2020). Students, on the other hand, are often absent from these conversations. While students are widely recognized as stakeholders in processes of pedagogical change, they are rarely depicted in a role which represents them as independent decision-makers. Instead, researchers have broadly focused on the student-related factors which can influence faculty during the implementation process. For example, instructors and administrators are often concerned with measures of student performance, students' affective perceptions of innovations, or students' demonstrated resistance to change. Perhaps as a result, literature rarely discusses students' own decisions and experiences as they engage with and implement the pedagogical innovations they encounter both inside and outside the classroom.

This is somewhat surprising, given the importance of student's self-directed (or self-regulated) engagement behaviors in the context of many contemporary educational innovations. Literature on blended learning, for example, has long acknowledged that the self-regulating behaviors of the students themselves are key to students' success in such resource-rich learning environments (Stacey & Gerbic, 2008). Despite this, implementation literature in EER rarely portrays students as anything more than an environmental variable, one of the many factors which influence instructors' implementation decisions within their unique institutional context. For example, in the 2014 *Journal of Engineering Education* special issue on systematic change in STEM higher education (McKenna, Froyd, & Litzinger, 2014), students were almost exclusively represented in the form of a "student resistance" variable. Even literature specific to the

implementation of blended learning presents students as an "external influence" (for example: Brown, 2016), when it gives a role to students at all (for example: Porter et al., 2016).

For the past five years, I have worked as part of a team examining the implementation and use of innovative pedagogical practices in undergraduate Mechanical Engineering in the context of a blended learning environment called *Freeform*. Although some of this work has included gathering observations of, and reflections from, faculty participants (DeBoer et al., 2016a; Evenhouse et al., 2018a; Evenhouse et al., 2018b), most of the analysis and subsequent writing I took part in has centered on students' reported experiences as they navigate innovations in pedagogy and educational technology in-class and as part of their personal studies (Evenhouse et al., 2018a; Evenhouse et al., 2018b; Evenhouse et al., 2020). As a result, this prior work has demonstrated that students likely go through their own processes of implementation when they encounter pedagogical change. Work by Stites (2017) analyzed *Freeform* students' use of a wide range of learning resources. Cluster analysis identified nine different patterns of resource usage demonstrated by the students (Stites et al., 2019), and showed that these different patterns of resource usage, with few exceptions, did not coincide with significant differences in academic performance (Stites et al., 2020). Likewise, work by Evenhouse et al. (2018a) noted that both the instructor and students at an external adopting institution experienced a period of transition at the start of their first semester using *Freeform*. Both students and instructor adapted to new course resources and instructional strategies over time. Further research at Purdue University further examined students' study habits and use of learning resources, demonstrating that students were influenced by a variety of individually distinctive factors comprising personal goals, scheduling limitations, individual preferences, background factors, and prior educational experiences (Evenhouse et al. 2018a, Evenhouse et al., 2020; Kandakatla et al., 2020). Even personal context, such as students' housing situations, could influence how they employed or engaged with their learning resources in the Freeform environment (Evenhouse et al. 2018a; Evenhouse et al., 2020).

Thus, our research has shown that students' own decision-making plays a key role in students' engagement with *Freeform* resources, resulting in individually distinct implementations of educational innovations. If we assess the implementation as a whole in light of this information, we see that students' impact on the implementation of education innovations is not limited to the feedback they provide to faculty. Rather, their own individual implementation decisions can have a direct impact on the results of faculty implementation efforts. While faculty-focused perspectives

have certainly proven useful for understanding and facilitating the process of implementation in EER, they may be implicitly limiting our understanding of students' experiences, and the roles students can individually play in the implementation of pedagogical innovations (Kezar, Gehrke, & Elrod, 2015). In contrast to traditional models of instructor-centric implementation, I believe there is value in examining students' experiences of implementation in context with their own interactions with educational innovations. Through such a line of inquiry, I believe that STEM researchers and educators may be better able to understand and promote the application, implementation, and success of educational innovations in the undergraduate context. For this reason, I have conducted this study to answer the following research questions:

Research Questions

RQ1. In what ways do students experience the process of implementation when they encounter educational innovations in *Freeform* at Purdue University?

    RQ1.1. In what ways do students relate to, and interact with, educational innovations in the Freeform environment?

    RQ1.2. What describes these developing relations, and how can they be categorized?

RQ2. In what ways can we represent students' experiences of implementation to inform future course design decisions from an authentically student-driven perspective?

    RQ2.1. What components are necessary to describe and represent the ways in which the student participants experienced implementation?

    RQ2.2. How can these components be related to one another in a way that is authentic to the students' interactions with the Freeform Dynamics environment?

    I have chosen two methods to help me address each of these research questions, and therefore the wording of my RQs reflects some of the philosophical and theoretical underpinnings of those methods. RQ1 discusses the relations between students and the innovations they implement, intentionally invoking the relational ontology employed in phenomenography. RQ2 discusses what components might be necessary to present those results in a way that is authentic to the students' reported experiences. I plan to use narrative analysis to take those disparate components and weave them together in a way that is representative of the students' own stories and implementation experiences.

Introducing the *Freeform* Environment

The *Freeform* environment refers to a comprehensive approach to instruction which has been iteratively developed, researched, and propagated through the joint effort of faculty in the Purdue University – West Lafayette (PUWL) Schools of Engineering Education (ENE) and Mechanical Engineering (ME). Originally conceived as a means of enhancing teaching and learning in the context of Sophomore-level Dynamics courses (Rhoads et al., 2014), the *Freeform* environment has since been applied to a variety of other courses in the ME mechanics-track curriculum (Kandakatla et. al, 2018). As part of an NSF-funded research project (DUE-1525671), *Freeform* has also spread to a number of partner institutions both within and beyond the Purdue University network (Evenhouse et al., 2018a; Kandakatla et al. 2018).

The pedagogical innovations involved in the *Freeform* environment can be summarized as a combination of three research-based instructional strategies: active learning, blended learning, and collaborative learning. This gives rise to what *Freeform* developers refer to as an ABC learning environment, an environment which leverages best practices from all three pedagogical approaches. This ABC framework ideally influences all aspects of teaching and learning experiences within *Freeform* courses including day-to-day instruction, student-student and student-faculty interactions, the development and use of learning resources, and students' own approaches to, and conceptions of, learning in engineering education.

Active, Blended, and Collaborative Learning in the *Freeform* Context

The combination of active, blended, and collaborative learning in the *Freeform* environment both engages students in their own learning processes, and allows students to self-direct those learning processes to better address their personal learning needs. Active learning itself requires that student engagement in learning be not only cognitive, but also behavioral, presenting students' participation in learning as something which must be actively demonstrated (Bonwell & Eison, 1991; Christie and de Graaff 2017). Chi et al (2014) for example, proposed a four-part framework for categorizing students' learning behaviors from Interactive to Passive. Passive behaviors are distinguished from the other three parts of the framework by the visible lack of student participation in the learning process, and instructors are encouraged to intentionally limit their use of Passive pedagogical approaches. Following this reasoning, traditional lecturing is often

deemphasized in active learning environments, as traditional approaches to lecturing rarely engage students in an active manner (Bonwell & Eison, 1991). A wide variety of studies have supported the efficacy of active learning to help students improve their retention of conceptual knowledge, develop thinking skills, and enhance their overall course performance (Freeman et al., 2014).

Hoic-Bozic et al. (2009) describe active learning as a process through which students are empowered to construct their own meaning and conceptual understanding of information through experience. They go on to discuss how blended learning environments can be used to promote such active learning experiences. Blended learning is an intentional integration of in-class learning opportunities with digital, online learning elements (Halverson et al. 2014; Means et al. 2009; Porter et al., 2014). This definition can include flipped courses (where in-class lecturing is entirely replaced by learning opportunities facilitated online) or, like *Freeform*, can combine digital resources, collaborative learning activities, and in-class instruction all within a single learning environment (Oliver & Trigwell, 2005). Like active learning, a variety of literature on blended learning has demonstrated positive outcomes for students' performance and course perceptions when compared to similar courses that do not employ digital learning elements (Halverson et al., 2014; Means et al., 2009).

Collaborative learning provides students with structured opportunities for interaction with their peers throughout the learning process (Barkley, 2014; Dillenbourg, 1999). Although collaborative engagement is rightfully considered to be a form of active learning (Chi et al., 2014), there have been a variety of studies both in traditional and blended environments demonstrating the additional benefits that collaborative learning opportunities can provide for student learners (Smith et al., 2005; Barkley, 2009). These can include better retention of information, greater persistence, and increases in class attendance (Preszler, 2009; Armbruster et al., 2009; Prince, 2004). Through the use and combination of active, blended, and collaborative pedagogical approaches, *Freeform* seeks to leverage these benefits both inside and outside of the classroom. For example, the *Freeform* course blog combines active, blended, and collaborative learning opportunities by incorporating course information, video resources, and online discussion forums into a single online location.

Building Blocks of the *Freeform* Environment

     Freeform is most fundamentally a blended learning environment, and thus has a variety of physical, digital, and interactive resources available for students' use. Although *Freeform* courses are not fully flipped, meaning that there is still faculty-driven instruction occurring in the classroom, students have access to a variety of videos which they can use to supplement their own learning. These videos can all be accessed from a course blog site which also houses homework assignments, course information, communications from the instructor, and an online discussion forum. The discussion forum is intended to foster collaboration and build community among students in the digital domain, combining blended and collaborative learning practices. This supplements the community building that already occurs in the classroom and around campus (Kandakatla et al., 2020).

     In contrast to this, the course lecturebook [an enhanced textbook (Adiguzel, Kamit, & Ertas, 2020) specific to the *Freeform* environment] demonstrates a deliberate combination of active and blended learning practices. The lecturebook was designed to explain key concepts and methods while minimizing the theoretical discussions and pre-worked examples typically included in other textbooks (Rhoads et al., 2014). Instead, each page of the lecturebook contains a generous amount of white space for notes, and each chapter includes a number of lecture-example problems at the end of the text. This design was adopted to encourage students' active involvement in their own learning by facilitating in-class notetaking and self-directed engagement with a library of lecture-example solution videos available through the course blog site. By the end of the semester, many students have "basically written their own book", to use the words of one *Freeform* developer, a process which is hopefully made less taxing due to the lecturebook's lower cost when compared to traditional textbooks.

     At PUWL, most of the *Freeform* resources and learning opportunities which students encounter can be said to incorporate a combination of active, blended, or collaborative learning elements, as demonstrated in Figure 1 below, adapted from Kandakatla et al. (2020). An explanation of these resources can be found in Table 1 below, adapted from Evenhouse et al. (2018a).
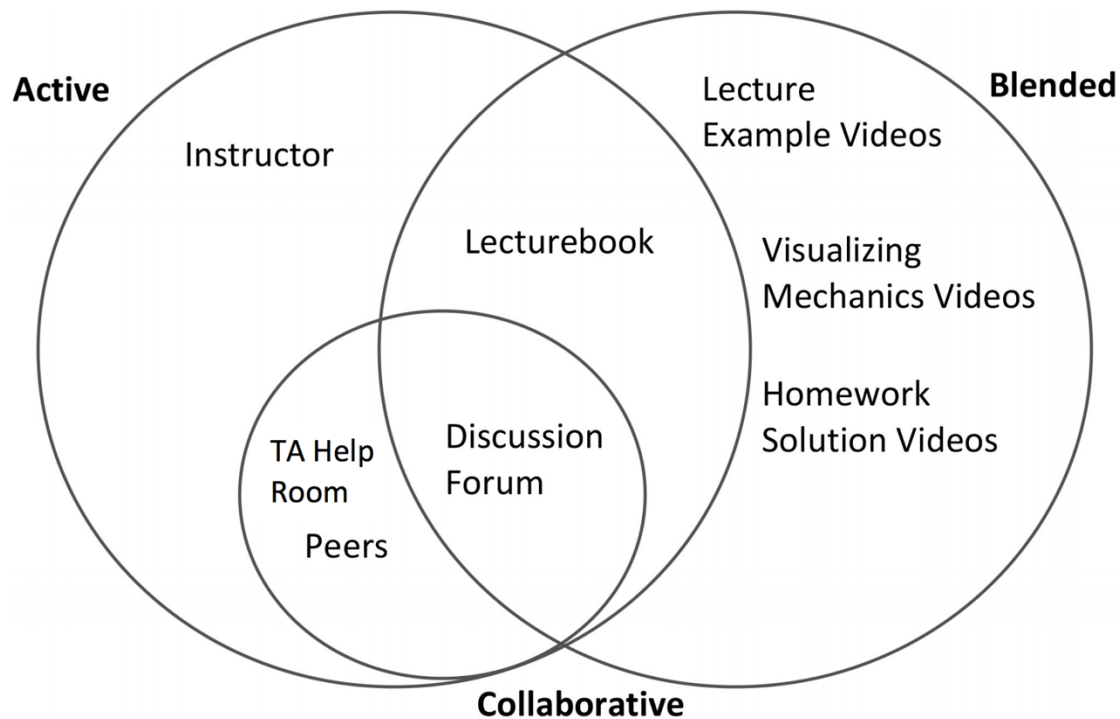
Figure 1: Diagram of active, blended, and collaborative learning resources in the *Freefrom* environment. Adapted from Kandakatla et al. (2020).

Table 1: Resources in the *Freeform* environment, adapted from Evenhouse et al. (2018a).

Resource	Contribution to the *Freeform* Environment
Course Lecturebook	The lecturebook acts as the *Freeform* equivalent of a textbook. It contains ample white space so that students may take notes or write-out solutions alongside the text itself. The text includes equations, derivations, example problems, and conceptual questions.
Instructor Office Hours	The instructor's office hours are a predetermined set of times each week during which students may interact with their instructor in-person to ask questions about the course, its content, or their assessments.
TA Help Room	The Teaching Assistant (TA) help room, similar to instructor office hours, allows students to request help from course TAs at a predetermined location during a set schedule each week.

(continued)

Online Solution Videos*	*Freeform* maintains an online library of narrated videos which provide step-by-step solutions to lecture examples (from the lecturebook) and completed homework problems.
Demonstration Videos*	Students were employed to create videos for the *Freeform* environment which demonstrate real-world applications and embodiments of fundamental Dynamics concepts. A library of these videos is maintained online under the name Visualizing Mechanics.
Discussion Forums*	Each class in the learning environment has a designated forum for online discussion and collaboration pertaining to homework assignments and exams.
Peer Collaboration	Students were encouraged to collaborate with their peers from Dynamics both inside and outside the classroom. Although this is not a resource provided directly to the students, it remains an essential part of the *Freeform* environment.

*The Online Solution Videos, Demonstration Videos, and Discussion Forums are all made available through the Freeform *course blog, along with homework assignments and general course information.*

In practice, the ways which students choose to implement their learning resources are an essential part of what makes the *Freeform* environment work. A student-centered perspective on the part of the instructor (Kember & Gow, 1998) and self-directed learning on the part of the students (Pintrich & de Groot, 1990) allows them to freely direct their own learning processes, fitting their studies directly to their own personal needs and preferences (Newman, 2002, 2008; Puustinen & Rouet, 2009; Zimmerman, 2001). This freedom on the part of both students and faculty is what inspired the name *Freeform* in the first place (Rhoads et al., 2014). The RQs of this current study build upon our research mission and prior findings; while framing students' engagement with *Freeform* as a process of implementation might be novel, it fits well with the spirit, purpose, and findings of the *Freeform* project itself.

LITERATURE REVIEW

Defining and Scoping Implementation

Hereon when I refer to *implementation*, I am referring to the process through which an individual or group incorporates an innovation into their ongoing practices. Such innovations may take the form of products, processes, behaviors, or even mindsets. *Adoption*, also referred to as *initiation*, denotes the beginning of the implementation process during which the innovation is first tested and applied by implementors (Taylor et al., 2018b; Tornatzky & Klein, 1982). *Adaptation,* also referred to in Rogers' (2003) diffusion theory as *reinvention*, is the process by which an innovation might then be adjusted to fit the unique needs of its new users or context (Aarons, et al., 2019; Baumann, Cabassa, & Stirman, 2017). The process of implementation is completed when an innovation achieves a long-term steady-state, becoming an essential part of the implementor's ongoing practices with no immediate need for further targeted adaptation (Moullin et al., 2019; Rogers, 2003). This final part of the process is referred to as *institutionalization* (Fullan, 1989; Zhu & Engels, 2013), or sometimes *integration* (May et al., 2009).

Some scholars use the word 'implementation' to refer specifically to the contextual adaptation of innovations, while others equate the words 'implementation' and 'adoption', positioning adaptation as an entirely different topic (Taylor et al., 2018b). For the sake of clarity, I will use the word 'implementation' to refer to a whole, time-dependent process of development and assimilation unless specifically stated otherwise. Implementation, as I describe it, is an organizational concept comprising an initial period of *adoption*, a variable process of *adaptation* as the innovation is adjusted to its new context, and finally the innovation's *integration* for regular use in a long-term, steady-state form.

It is also useful to define implementation by what it is not. Literature on the implementation of innovations is often conflated with literature on the diffusion of innovations, blurring the lines between these two processes. In Rogers' (2003) diffusion of innovations model, the process of diffusion can only begin when potential implementors become aware of the innovation in question. After an extensive period of persuasion and experimentation, potential users make a decision whether or not to adopt the innovation, then move on to a continued process of implementation. More adjacent to the topic of this paper, Graham, Woodfield, and Harrison (2013) developed a

model for the adoption and implementation of blended learning that follows a similar trajectory: institutions are first made fully aware of blended learning allowing them to experiment with it, adopt it, and eventually implement it over the course of time. Although one model nominally targets diffusion, and one nominally targets implementation, both feature the targeted process of "implementation" itself as one smaller segment of their larger theoretical framework.

In their paper discussing change strategies for use in STEM higher education, Borrego and Henderson (2014) present diffusion and implementation as two separate approaches to promoting change in higher education curriculum and pedagogy. Diffusion is heavily dependent on sharing knowledge, experimentation, and persuasion, presenting the adoption of innovations as a multi-phased process that is highly social in nature. Implementation, on the other hand, is a targeted process of change, in which innovations are intentionally introduced to new environments by people who act as agents of change. These agents of change typically introduce the targeted innovation alongside a set of strategies that are specifically designed to promote that specific innovation's efficacy: the most important of which are generally mechanisms for training, performance evaluation, and user feedback (Borrego & Henderson, 2014).

For the purpose of this paper, frameworks which disambiguate the dissemination of information and the propagation of innovations will be called *models of diffusion,* regardless of the terminology used by the original authors. Models of diffusion tend to include implementation as only one part of a larger framework, focusing heavily on processes of knowledge sharing and persuasion which precede the implementation process. *Models of implementation* begin with the adoption of innovations and talk about the process through which innovations are incorporated into regular practice in great detail, examining the interactions which occur between adopted innovations, users, and the various external factors which influence them.

Students in the Implementation of Active, Blended, and Collaborative Innovations

As *Freeform* is characterized as an ABC environment, there is benefit in examining literature specific to the implementation of active learning, blended learning, and collaborative learning innovations. Much of the literature in this review will draw from the blended learning space, as blended learning environments can easily incorporate both active and collaborative pedagogical approaches and align most effectively with the context of the *Freeform* environment itself. In fact, a number of authors have identified design for active learning (Bower et al., 2015; Hoic-Bozic,

2009, Haak, HilleRisLambers, Pitre & Freeman, 2011) as well as for peer collaboration and student-faculty interactions (Wang, Huang, & Quek, 2018; Bernard et al., 2009; Hoic-Bozic et al., 2009), as key to the success of implementations of blended learning.

There are few examples of studies which evaluate blended learning in context with implementation strategies or instructional practices that are specific to blended environments (Brown, 2016; Taylor et al., 2018a). Those studies specifically targeting the implementation of blended learning rely heavily on literature related to the adoption, implementation, and use of the specific educational technologies being employed, rather than the environment as a whole (For example: Porter et al., 2016; Maclaren, 2018). However, there is a wealth of literature on blended learning highlighting the perceptions and outcomes demonstrated by student populations (Bernard et al., 2014; Francis & Shannon, 2013; Means et al., 2014). These studies have helped to build up a robust corpus supporting the efficacy of blended learning practices in higher education.

In some cases, these studies tie commonly evaluated implementation outcomes to the characteristics of student participants (Wladis, Conway, & Hachey, 2017; Kintu, Zhu, & Kagambe, 2017). However, those rare studies containing formalized frameworks and models of blended learning implementation follow the broader trends of STEM implementation literature by featuring students as an environmental factor (for example, see: Brown, 2016; for an exception, see: Anthony et al., 2020), when they feature students at all. For example, the implementation framework by Porter et al. (2016) does not include students as an influencing factor. These approaches persist despite the regular acknowledgement that students' own self-directed learning behavior is fundamental to their blended learning experiences. Singleton (2012) for example, concludes their dissertation saying,

> "Students must take ownership of their learning and not merely be bystanders… In order for an institution to be successful in the transition [to blended learning] front-end planning which includes policy, planning, resources, scheduling and support are needed. During a successful implementation support services are needed by both faculty and students." (Singleton, 2012: pg. 105)

Moskal, Dzuiban, and Hartman (2013) make a similar exhortation in their paper discussing the implementation of blended learning and its impacts on various stakeholder groups in higher education,

"Students must re-examine their assumptions about how they will navigate the educational system and just what will be required of them in this environment that represents the confluence of technology and face-to-face learning." (Moskal, Dzuiban, & Hartman, 2013: pg. 23)

Yet, this excerpt is followed by the exact same analytical practice seen in so many other studies of blended learning: reducing students to survey-generated satisfaction scores and course-generated statistics relaying the students' academic performance. Looking more broadly, in their recent systematic literature review on the factors impacting faculty adoption of innovative learning technologies, Liu, Geertshuis, and Grainger (2020) briefly mention students as "participants and collaborators in the adoption process", but also in the next sentence as, "the recipients of academics' pedagogical practices" (Liu, Geertshuis, & Grainger, 2020: pg. 8). Students' feedback and grades are only briefly mentioned, making up a small part of one theme in a 16-theme framework dominated by administrative, institutional, and professional considerations.

While studies of implementation seem to overlook students' own actions and decision-making in the context and evaluation of their blended resources, students' own self-regulated learning behaviors are widely recognized as a critical component driving student success in blended learning environments (Stacey & Gerbic, 2008; Kintu, Zhu, & Kagambe, 2017). Unfortunately, factors which affect students' decisions to engage with physical resources cannot be assumed to translate directly into digital contexts (Hao, Barnes, Wright, & Branch, 2017), implying a need for research into students' own resource usage and engagement decisions in the context of blended learning implementations.

For example, it is important to note that students may not inherently know how to use the digital resources they encounter in support of their own learning (Stacey & Gerbic, 2008). Students' prior experiences with technology can facilitate effective engagement with blended learning resources, but that experience does not always translate into an ability to pursue learning and find information in digital environments (Schwenger, 2016; Tang & Chaw, 2016). This has led students to request orientation information, guidelines, instructions, and other resources to help them adapt their study habits to better accommodate digital resources (Taylor & Newton, 2013). Adaptations such as these are required due to the unique affordances and requirements of blended learning environments (Gedik, Kiraz, & Özden, 2012). In fact, Tang and Chaw (2016) concluded that students' demonstrated ability to adapt in the presence of technological innovations is a significant predictor of whether individual students are ready to engage with blended learning innovations.

Students who fail to adapt can report feeling "lost" and "overwhelmed" by their environment as a result (Taylor & Newton, 2013 pg. 56). Promoting adaptation by intentionally preparing and orienting students (Gedik, Kiraz, & Özden, 2012; Valencia, 2008) or by providing them with ongoing mentorship and tech support (Wach, Broughton, & Powers, 2011) enables self-regulated learning behavior and fosters student success in blended learning contexts.

This need for support emphasizes the importance of communication in blended learning, both between student peers, and between students and their instructors. Students look to instructors to facilitate learning and look to their peers to guide their behavioral norms (Cheung & Vogel, 2013; Symeonides & Childs, 2015). Instructors can direct and facilitate engagement with digital resources (Martin & Bolliger, 2018; Martin, Wang, & Sadaf, 2020), and peer interactions can form that engagement into positive, community-driven experiences (Wang, Huang, & Quek, 2018; Symeonides & Childs, 2015; Phirangee, 2016). In addition, students can provide constructive feedback to their instructors to help guide course development (Taylor & Newton, 2013). Collecting such student feedback is a widely encouraged practice to provide institutional implementations of blended learning with guidance and support (Taylor et al., 2018a), much as user feedback is encouraged in broader implementation literature.

Student resistance is a widely acknowledged factor in determining the success of instructional innovations (Borrego & Henderson, 2014, Tharayil et al., 2018), and may be the most infamous form of student-generated feedback in innovation literature. Student resistance has been extensively studied in the context of active learning innovations in STEM education, inspiring a variety of publications discussing strategies which instructors may employ to mitigate student resistance to their active learning opportunities. The past half-decade has seen a shift in discussions of student resistance from a focus on *open resistance* (such as students refusing to engage in active learning exercises, or leaving negative reviews about the course or the instructor), to *passive resistance* (such as an unwillingness to participate in activities, or slacking-off during group work) (Finelli & Borrego, 2020). This shift has coincided with research demonstrating that open resistance tends to be rare in active learning environments (Nguyen et al., 2017), and has little perceived impact on instructor's implementation behaviors in blended learning environments (Dzuiban et al., 2018).

Nguyen et al (2017) found that the pedagogical actions taken by instructors are more predictive of student engagement behavior than the students' own prior experience with active

learning innovations. In their latest book chapter titled *Evidence Based Strategies to Reduce Student Resistance to Active Learning*, Finelli and Borrego (2020) reviewed a broad base of literature to present a comprehensive set of recommended strategies for instructors to reduce student resistance. These strategies fall into one of three categories: planning, explanation, or facilitation. While the *planning* strategies are entirely instructor-facing, strategies that fall into the categories of *explanation* and *facilitation* involve interactions between the instructor and their students. Explanation strategies help instructors to better introduce and orient students to new active learning activities, and facilitation strategies help instructors to promote and retain student engagement throughout the course of their active learning implementation. Of the two, facilitation strategies have proven to be most influential in reducing student resistance to active learning (Finelli & Borrego, 2020).

This is not necessarily surprising, as instructors' actions to facilitate engagement have likewise been promoted in literature on collaborative learning, and most especially in the context of collaborative learning activity which occurs online (Martin, Wang, & Sadaf, 2020; Epp, Phirangee, & Hewitt, 2017). Many studies recommend that instructors take an active and participatory role in students' collaborative engagement by encouraging discussion (Lewis & Abdul-Hamid, 2006) and by maintaining a *teaching presence* in the context of students' collaborative activity (Garrison & Cleveland-Innes, 2005; Garrison, Cleveland-Innes, & Fung, 2010, Shea, Li, Swan, & Pickett, 2005). Although online collaboration is already acknowledged as being beneficial for student learning in online environments (Moore, 2011), facilitative actions of the part of the instructor can lead to greater student engagement and deeper learning outcomes (Garrison, Cleveland-Innes, & Fung, 2010, Martin & Bolliger, 2018).

Students Implementing Active, Blended, and Collaborative Innovations

While it is useful to understand the role that students take in more faculty-centric literature on innovation, engagement, and implementation, these works tell us little about the actual motivations, decision making processes, and self-directed engagement behaviors of the students themselves. To learn more about how, and why, students might choose to engage with pedagogical innovations, we can examine literature on self-directed and self-regulated approaches to learning.

The Theory: Self-Directed Learning and Expressions of Student Agency

Student agency is the conceptual measure of students' capacity to act and effect change in the context of their own learning experiences (Martin, 2004). Most often, student agency is facilitated through the provision of *choice*. Allowing students to choose between many options or opportunities for learning allows them to exercise agency and take ownership of their own experience. Allowing students to make such agentic decisions, and to see the results of those decisions manifested in their own learning, has been shown to increase students' overall engagement with learning and their perceptions of learning relevance (Lindgren & Mc Daniel, 2012).

If student agency describes the provision of choice, self-directed learning describes the way in which students use that agency effectively. Self-directed learning describes the process through which students select, plan, carry-out, and evaluate the efficacy of their own learning experiences. In self-directed learning, the choice to engage with specific opportunities for learning lies – at least partially – with the students, rather than being wholly directed by their instructors. Therefore, self-directed learning relies heavily on students' own internal motivation to learn, their own understandings of how learning works, and their own abilities to plan ahead, set goals, and assess whether those goals have been met (Litzinger, Wise, & Lee, 2005).

Jossberger et al. (2010) distinguish between the terms "self-directed" and "self-regulated" learning by delineating the *scale* of each concept. Self-directed learning is described as encapsulating the entirety of the students' learning experience, requiring that students recognize and seek-out their own opportunities for learning. Self-regulated learning, in contrast, is conceptualized as applying to specific instances of student engagement with individual learning opportunities. In this way, self-regulated learning is one small part of self-directed learning. In self-directed learning, students are able to choose which tasks they will engage with in order to achieve their learning goals. When those choices are made, students may then employ self-regulated learning in order to maximize their learning outcomes from each task (Jossberger et al., 2010; Loyens, Magda, & Rikers, 2008). In practice, the methods by which students execute self-directed and self-regulated learning are very similar. The practice of each may be broken down into three essential steps: initial planning and goal-setting, active and metacognitive engagement, and a post-hoc evaluation of learning outcomes. For this reason, Jossberger et al. (2010) describe

self-directed learning as the *macro* perspective, and self-regulated learning as the *micro* perspective on what is, in effect, the same approach to learning.

When evaluated in the context of problem-based learning (PBL), a pedagogical innovation widely utilized in STEM education fields, self-directed learning aptitude has been shown to be predictive of higher grades for students (Stewart, 2007). Beyond these benefits however, many writers in engineering education (for example: Litzinger, Wise, & Lee, 2005; Stewart, 2007, Jordaan & Havenga, 2020) also echo a general trend in higher education (for example, Zhoc, Chung, & Bing, 2018; Morris, 2019) by framing self-directed learning aptitude as an essential professional competency for new engineers. Self-directed learning ability is framed as being indicative of students' ability to tackle complex, real-world problems and engage in life-long learning – both of which are ABET learning criteria.

Just as students must assess problems, select from a range of resources, create informed solutions, and evaluate those solutions in light of their own goals in the context of PBL (Savery, 2015); students in blended learning must assess their own learning needs, select from a range of resources they have at their disposal, engage in out-of-class learning and, ideally, evaluate their own learning outcomes at the conclusion of their work (De George-Walker & Keeffe, 2010). The potential of blended learning to not only improve students' performance, but to also contribute to the acquisition of professional engineering competencies, marks it as an important innovation for use in undergraduate engineering education.

Self-directed learning readiness has long been discussed as an essential contributor to student success and positive student perceptions of learning in blended learning environments (Ausburn, 2004). Researchers have also speculated that engaging with blended learning could help students to develop their own self-directed learning aptitude. For example,

> "Through effective facilitation, instructors can support students in understanding what it is they are expected to learn, the choices they have available to them when learning and can assist them to develop the necessary skills of reflection, self-direction and self-management. Therein lays the potential for blended learning to provide the flexibility, independence and responsibility, plus metacognitive processes, necessary for the development of the self-determined learner." (De George-Walker & Keeffe, 2010)

While some studies have indeed confirmed that blended learning can help to improve students' self-directed and self-regulated learning skills beyond what could be expected in traditional learning environments (for example: Uz & Uzun, 2018), others have proven inconclusive (for

example: Sirakaya & Ozdemir, 2018). In short, blended learning does not automatically teach students how to self-direct or self-regulate their own learning: rather, many approaches to blended learning have been found to contribute nothing to students' readiness for self-directed learning engagement (Adinda & Mohib, 2020). Instructors must *design for* the enhancement of students' self-directed and self-regulatory learning behaviors for such development to reliably occur (Adinda & Mohib, 2020; Van Laer & Elen, 2020)

Unfortunately, there are still few works discussing how best to foster self-directed learning in blended learning contexts through design of the environment or pedagogy. As a result, Van Laer & Elen (2020) proposed their own list of seven attributes that they believe typify the facilitation of self-direction in the blended learning context. Those traits are: Authenticity (demonstrating real-world relevance of learning), Personalization (fostering fit with individual students' needs and values), Learner Control (providing opportunities for student self-direction), Scaffolding (creating zones of proximal development), Interaction (encouraging engagement with the learning environment and its resources), Reflection cues (prompting metacognitive examination of the learning experience), and Calibration cues (prompting a self-evaluation of learning outcomes). These traits are intended to foster students' internal motivation, facilitate the adoption and implementation of blended learning resources, and encourage metacognitive and reflective learning practice in the presence of blended learning innovations (Van Laer & Elen, 2020). It is also worth noting that designing for one of these attributes without including the others is likely not enough. Simply allowing for Learner Control through the provision of blended learning resources has proven insufficient to guarantee students' growth as self-directed learners. As another example, Tsai, Perrotta, and Gašević (2020) found that the intentional Personalization of individual students' learning experiences was not enough to foster a feeling of student agency. In summary, each of these attributes must work in concert to draw-in and empower students to pursue their own learning in the blended learning context.

The Practice: Students' Demonstrated Priorities and Preferences in Blended Learning

Looking beyond the realm of theory, there are many observations that can be made regarding how, and why, students self-direct in blended learning. A broad range of studies have been published regarding the perceptions and preferences of students in blended learning, including a few from within the *Freeform* environment itself. For example, Evenhouse et al. (2020)

focused on the twin concerns of resource relevance and availability. *Freeform* students seemed to prioritize resources that they personally believed to hold information that was relevant to their learning needs (eg: information that was trustworthy, aligned with their assessments, or personalized to their own questions) and was readily accessible when needed (eg: not prevented due to scheduling, could be accessed within a reasonable delay). However, students' perceptions of which resources were *most* relevant, or *most* accessible, differed wildly (Evenhouse et al., 2020). In addition, students did not always engage with the resources which they perceived to be most useful (Wirtz et al., 2018) or even most accessible (Evenhouse et al., 2020), complicating popular models of student engagement such as the expectancy value model (Makara & Karabenick, 2013).

Drawing from an assortment of blended learning literature, students in blended learning environments appear to prioritize resources that make critical information easily accessible and are well-aligned with their course's content (Taylor & Newton, 2013; Maclaren, 2018; Wang, Huang, & Quek, 2018, Stites et al., 2019, Evenhouse et al., 2020; Haak, HilleRisLambers, Pitre, & Freeman, 2011) as well as resources that are relevant to their anticipated assessments in the course (Grund, Grote, & Gerber, 2004; Maclaren 2018; Dzuiban et al., 2018; Evenhouse et al. 2020). This means that students tend to employ resources that are created by their lecturer (Maclaren, 2018), or are otherwise structured in the same way as the content of their course (Taylor & Newton, 2013; Evenhouse et al., 2020) when available. This can also lead students to prioritize individually accessible resources in lieu of collaboratively generated content, like that which they encounter in online discussion forums (Grund, Grote, & Gerber, 2004; Stites et al., 2020). Many of these observations could be summed up as a need for *trust*: students look for resources which they can trust to help them work towards their personal learning goals (Evenhouse et al., 2020; Baehr, 2012). However, these decisions can also be influenced by the students' own personal circumstances, predilections, and even physical environments (Park, Martin, & Lambert, 2019; Kandakatla et al., 2018; Evenhouse et al., 2020), vastly complicating any discussions of student learning behaviors in blended learning contexts.

Students appear to appreciate blended learning environments that are well-structured in terms of their content and alignment (Taylor & Newell, 2013; Dzuiban et al. 2018; Evenhouse et al., 2018a, 2020), contain high-quality lectures and supplemental learning resources (Wang, Huang, Quek, 2018; Evenhouse et al. 2020; Gedik, Kiraz, & Özden, 2013), and include clear and effective communication between instructors, students, and their peers (Taylor & Newell, 2013; Dzuiban et

al., 2018). Although the overall quality and highly-structured nature of learning activities and resources has been tied to increases in student performance (Makitalo-Siegel, Kohnle, and Fischer, 2011) and increases in student engagement with their blended learning opportunities (Naibert et al., 2020), research has also demonstrated that students in blended learning environments can engage with the same sets of resources in behaviorally and cognitively distinct ways (Evenhouse et al., 2020, Stites et al., 2019), reflecting the opposing concerns of agency and structure in educational discourse (Lindgren & McDaniel, 2012). In addition, the individual patterns of resource engagement reported by students do not generally appear to be predictive of their consequent academic performance (Stites et al., 2019, 2020). Although some research suggests that students' cognitive engagement with their learning resources can be predictive of their academic outcomes (For example: Choy & Quek, 2016) *more* engagement does not always lead to additional benefits (Grund, Grote, & Gerber, 2008), and the actual resource usage behaviors of the students themselves have been largely neglected in literature.

Intersections of Implementation Theory and Innovative Instruction

Implementation is typically accompanied by preparatory actions in the form of training, orientation, and setting faculty expectations (Borrego & Henderson, 2014). Best practices in active, blended, and collaborative learning likewise call for instructors to help prepare and orient their students in advance of instruction (Taylor et al., 2018a; Finelli & Borrego, 2020; Martin, Wang, & Sadaf, 2020). Although these best practices were established through the study of various different topics (mitigating student resistance, facilitating resource usage, and increasing engagement in collaboration, respectively) the core of what they attempt to accomplish (fostering students' engagement with innovative learning opportunities) remains consistent.

As a targeted process of curricular change, implementation calls for agents of change to act as facilitators, supporting the adoption and use of innovative pedagogical methods. Instructors in active, blended, and collaborative environments are also encouraged to act as facilitators (Garrison, Cleveland-Innes, 2005; Deepwell & Malik, 2008), and are even described as being facilitators by their students (Garrison, Cleveland-Innes, & Fung, 2010). Implementation literature also emphasizes the importance of user feedback as a means of guiding adaptation, improving the user experience, and promoting the implementation's success (Borrego & Henderson, 2014).

Likewise, collecting and acting upon regular feedback from students is encouraged in active, blended, and collaborative learning literature (Brown, 2016; Finelli & Borrego, 2020; Sher, 2009).

The similarities between best practices in innovative instruction, and best practices in implementation literature, are striking. This highlights a strange duality. Supporting, facilitating, and collecting feedback from users who implement innovations is touted as key to the success of the implementation processes. Yet, despite the importance researchers place on student behaviors, performance, and feedback, students are never cast in the role of "implementor". While students have been depicted as stakeholders in implementation and as active participants in the final form of implemented innovations (Koenen, Dochy, & Berghmans, 2015), implementation literature in EER is focused on professional development of faculty for the purpose of enhancing learning opportunities for students through the introduction of educational innovations (Mirriahi et al. 2015; Liu, Geertshuis, & Grainger, 2020; Finelli & Borrego, 2020). These studies seem to overlook the questions of how, and why, students themselves might implement those innovations to benefit their own learning.

Finelli and Borrego (2020) start their section on "Future Work" in the study of student resistance by saying, "We believe that one important direction for future work involves student affective responses to active learning (i.e., the value they place on the instruction and how positively they feel about it)," but end the section by introducing their workshop on overcoming student resistance, saying that its purpose is, "to introduce the research-based benefits of active learning, present our strategies to reduce student resistance, and empower the instructors to create action plans to take back to their instruction." The affective perceptions and value which implementors ascribe to innovations have already been a focus of implementation research. Likewise, affective perceptions and expected value have been used to frame students' use of study resources in both traditional (Makara & Karabenick, 2013) and blended (Evenhouse et al., 2020) environments. Rather than continuing to focus our efforts on understanding and smoothing the implementation processes of faculty, perhaps it is time for a shift in perspective; one that views students as actors and decision makers in the context of educational innovation, rather than simply as the recipients of innovative instructional methods.

Modeling the Implementation of Innovations in Higher Education

Depictions of Implementation in EER Literature

As discussed above, in their publication outlining change strategies in STEM Higher Education, Borrego and Henderson (2014) introduced implementation in higher education as an intentional and targeted process of curricular change. Through implementation, the introduction of specific innovations to new environments is facilitated by strategies that are designed to promote their efficacy. Ideally, these intentional processes of implementation result in the successful, effective, and long-term use of research-based innovations in instructional practice. However, this process of change itself is complex and multifaceted. Henderson & Dancy (2006) have long modeled change in higher education through a combination of factors that can be both individual and situational. Individual abilities and inclinations to innovate must be considered alongside outside influences and environmental factors for educational change to be properly understood (Lattuca and Stark, 2009). As such models typically assume that the implementors of these innovations are administrators or faculty, students are often included as an environmental factor (Taylor et al., 2018b) exerting an influence on the actions of instructors.

The importance of environmental factors in models of implementation becomes especially apparent when considering the nature of local adaptations. Instructors expect to be able to fit new pedagogical practices, curricular changes, or educational technology to the needs, abilities, and preferences of both their institutional context and their students themselves (Henderson & Dancy, 2006; Dancy & Henderson, 2008). Such adaptations are recognized as a necessary part of the implementation process, allowing innovations to be applied broadly despite differences in institutional, cultural, or physical context. However, like the process of implementation, adaptations can also be undertaken on a personal basis. Strong personal conceptions of learning theory and effective teaching practice combined with a long history of educational experience not only change how faculty perceive educational innovations to fit their classrooms and students, but also change how they adapt those innovations for instructional use (Henderson, Beach, & Finkelstein, 2011). It is worth noting that these same concerns for both contextual (Cohen & Ball, 2007) and individual (Englund, Olofsson, & Price, 2017) adaptation are also reflected in broader literature on implementation in higher education. STEM programs are not the only ones wrestling with these issues.

Generalized Two-Part Model of Implementation

Although implementation has long been recognized as a complicated process involving many actors and influences both within the context of higher education and beyond (Harty, 2010; O'Toole, 1986), a number of research works have produced models in order to better understand, predict, and facilitate the implementation of innovations within organizations. When examined broadly, these models define three distinct groups of components which influence the success of an implementation: the details and traits of innovation itself, the actors who are conducting the implementation, and the environment in which the implementation takes place (Berkel, Mauricio, Schoenfelder, & Sandler, 2011; Moullin et al., 2019; Davis, 1989). As time has passed, the ways in which these three components are conceptualized have become increasingly defined and further complicated. Yet despite this development, the basic layout of relationships we use to model implementation has changed very little over time.

In earlier literature regarding organizational change, the relationships between an innovation, its implementors, and its environment were presented in what was effectively a two-part structure. After a thorough review of the literature at the time, Klein and Sorra (1996) laid out their model of implementation effectiveness for businesses in two parallel branches. New innovations were judged against two sets of determinants: the institutional or organizational climate (including barriers, enablers, skills, and incentives), and the individual implementors' perceptions of how well the innovation fits their needs (reflecting their individual motivations and commitment). These two separate branches of the model could be used to determine whether innovations could be successfully implemented in a new business environment.
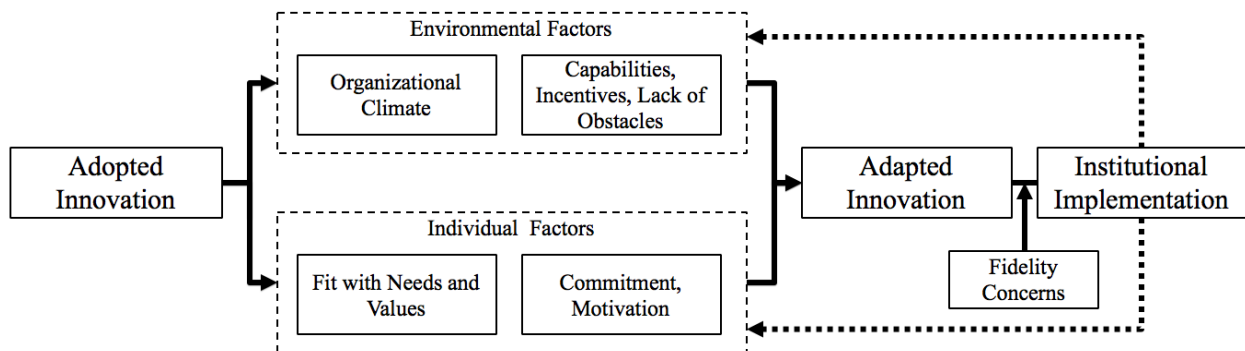
Figure 2: Klein and Sorra's two-branch model of implementation. Adapted from "Determinants and Consequences of Implementation Effectiveness" appearing in Klein & Sorra (1996) pg. 1056

The Klein and Sorra model has proven widely effective for understanding and supporting innovation in fields outside of education. This has been especially true in the case of technological and computer-based innovations. The authors went on to focus more specifically on computerized technological innovation (Klein, Conn, & Sorra, 2001), and a number of studies have verified the model's overall efficacy in these situations (Holahan, Aronson, Jurkat, & Schoorman, 2004; Dong, Neufeld, & Higgins, 2008) contributing to its continued use in modern discussions and reviews of implementation theory. Other implementation researchers have expanded upon our understanding of what each part of the model entails. Some have complicated what constitutes an 'implementor', treating implementors as entire networks of actors (Harty, 2010) or competing sets of stakeholders (Ramirez, 2001). Others expand on our understanding of the implementation environment, laying out complex webs of organizational structure and culture (Ruef, 2002; Zhu & Engels, 2013). For example, we can distinguish between environmental factors that originate within the institution (inner-context) or outside of the institution (outer-context) where the implementation takes place (Moullin et al., 2019). However, some of this same research has shown that the Klein and Sorra model cannot be considered comprehensive. In fact, it may be especially limited in scope when applied to innovations in education.

In practice, the two-branch model of implementation often fails due to its inability to account for the ways in which individual implementors can influence, and be influenced by, the environment around them. In finance, Ax and Greve (2017) identified how changes in environment due to an innovation's presence can alter individuals' values and priorities, breaking the two-part branching of the Klein and Sorra model. Harty (2010), who studied the implementation of tech-based innovations at multiple companies using actor-network theory, concluded that each institutional implementation could be treated as a fundamentally different product due to the unique adaptations that were required. In education, the effects relating individuals, innovations, and their environments may be even more pronounced. The prescribed, top-down approaches to implementation that are often useful for technological innovation in business have proven largely ineffective when fostering the implementation of research-based innovations in education (Dede, Honan, & Peters, 2005; Dancy & Henderson, 2008; Gurmak & Glenn, 2014). The adaptations required by institutional and pedagogical influences found in higher education likely require a more complex and nuanced perspective than can be provided by the original Klein and Sorra model.

Model of Implementation in Higher Education: Instructor-side

Adjusting the two-part model of implementation for use in education requires expanding on the number of ways in which implementors and environments may interact and relate with one another. For example, there are many environmental factors in higher education that can influence the needs and values of individual implementors. Researchers have reported on the influence of institutional policy (Dancy & Henderson, 2008; Koenen, Dochy, & Berghmans, 2015), organizational leadership (Taylor et al., 2018b), communities of practice (Ferlie et al., 2005; Guldberg & Mackness, 2009), and even external (outer-context) factors such as accreditation standards on the behaviors and values of instructors (Lattuca & Stark, 2009). Likewise, work on institutional change in higher education has identified how emergent and participatory strategies can help individual implementors effect change in their institutional environments, helping their context to better align with a desired innovation (Henderson, Finkelstein, & Beach, 2010). In short, any model of implementation amended for use in higher education should allow for complex relationships between individual implementors and their surrounding environment, acknowledging how the interactions between individual and environmental factors can drastically influence an implementation's progress and overall success.

It is also worth noting that external and internal environmental factors can exert an influence on one another. Just as communities of professionals can drive change within an organization, they can also push for change on the national or international stage (Lucena et al., 2008). Likewise, national regulations or requirements can exert an influence on institutional policies. Oftentimes, the external and internal contexts of an implementation are connected by *bridging factors*: actors or entities that mediate the influences that environmental elements can exert on one another (Moullin et al, 2019). For example, institutional leadership can arrive at different interpretations of national policy, mediating the effects of large-scale regulations on the climate and policies of their individual institutions (Volkwein et al., 2004). In short, environmental factors are not a single, unified entity, especially within the nuanced context of higher education.

Finally, within the context of higher education the origin of any implemented innovation, whether in the form of a developer, document, or other means of distribution, can exert a variety of influences on the implementation process. I have already discussed how implementation literature recommends that developers provide ongoing support to implementors, and that they collect feedback in order to inform future development and implementation efforts. In addition to

general support and feedback, developers of educational innovations can also help in the evaluation and revision of local adaptations which occur as part of the implementation process. Such evaluations examine *implementation fidelity*: the measure of how well a completed implementation reflects the originally adopted innovation. Due in part to the importance of adaptations in the success of implementation in academia, the study and evaluation of implementation fidelity has become increasingly prevalent (Berkel et al., 2011). Fidelity is determined by identifying a small set of *critical components* which represent the core requirements and concerns of the original innovation. Those critical components are then compared to the actual traits exhibited by the finalized, steady-state implementation. Implementation fidelity is high when no critical components are sacrificed during the implementation process. Conversely, implementation fidelity is low when critical components are lost due to adaptations which were imposed on the innovation over time (Borrego et al. 2013; Carroll et al., 2007). The evaluation of fidelity is often a critical step in determining the relative success of implementation processes, but not because high implementation fidelity is universally assumed to be beneficial (Moullin et al., 2019). Rather, it is important to understand how an innovation has been changed to fit its context to inform further changes or future implementations. Sometimes a loss in fidelity can impair the efficacy of an innovation. At other times, low fidelity simply reflects that many adaptations were necessary for the implementation to succeed.

Figure 3 adjusts the Klein and Sorra model to allow for the interactions described above. The two-part model separating individual and environmental concerns has been altered to reflect a multi-part relational framework. Arrows connect the individual and environmental factors, allowing for each to influence the other and shape the implementation process. Likewise, the relational framework includes the role of bridging factors connecting and mediating the external and internal environmental factors. Finally, the model also includes the critical-components of the innovation being adopted. The influence of the innovation and its developers are evidenced at three points in the model: they define the original innovation being adopted, they allow for feedback and support during the initial implementation process, and they facilitate the evaluation of implementation fidelity in light of any necessary adaptations.

Figure 3: An initial model of instructor-side implementation of educational innovations in higher education based on literature review

Borrego & Henderson (2014) note that an awareness of the critical components of an innovation can assist in its implementation. For this to happen, developers must make certain that the critical components their innovation are clearly communicated to users and are rigorously evaluated throughout the implementation process. This implies that, if the evaluation of any critical components of an implementation in education depends on the behaviors exhibited by the effected students, then students should naturally play an active and important role in the implementation of that innovation.

Model of Implementation in Higher Education: Student-side

Although information on students' own processes and experiences of implementation is scarce, there are still a number of observations which may be drawn from literature. Research has previously shown that students can affect instructors' processes of implementation, suggesting that students are able to directly influence their learning environment. Instructors may alter teaching methods in response to student feedback or performance (Evenhouse et al., 2018a; Taylor et al.,

2018b) on their own accord or due to mediation by administration (Miller & Higbee, 2020), and student resistance is an acknowledged factor in determining the success of instructional innovations (Borrego et al., 2013, Tharayil et al., 2018). Likewise, we know that environmental factors can have an effect on students' perceptions and values, changing their behavior while studying (Kandakatla et al., 2018). Considerations such as institutional policy, instructor expectations, scheduling concerns, access to technology, social pressures, and even broader factors such as housing conditions have reportedly influenced students' decision making as they engaged with educational innovations (Evenhouse et al., 2020; Zimmerman, 2001).

Prior research has demonstrated that students can go through processes of adaptation when studying, even beyond the context of Blended Learning. As one common example, students will adapt their study strategies during exam preparation based on instructor input and personal goals (Broekkamp & Van Hout-Wolters, 2007). These decisions are often made based on personal perceptions of the course, perceptions which may not align with those of their instructor. Gulikers et al. (2008) found that student perceptions of assessment authenticity are consistently lower than in their instructor's perception. In addition, different assessments align with different students' preferences and aptitudes, emphasizing that there is no one-size-fits-all innovative solution to assessment strategy (El-Kafafi, 2012), or to students' approaches to exam preparation.

Research has also long demonstrated that instructors' approaches to teaching and students' approaches to learning are related (Prosser & Trigwell, 1997). As discussed above, this has often proven true in the context of various research-based innovations; the facilitating actions of instructors play an essential role in encouraging student engagement and directing student behavior in active (Finelli & Borrego, 2020), blended (Taylor et al., 2018b), and collaborative (Martin, Wang, & Sadaf, 2020) learning environments. From these observations, we can conclude that any model of student implementation should allow for complex interactions between instructors, individual student implementors, and their environments. This means that our expected instructor-side and student-side models of implementation in higher education include very similar mechanisms and, as a result, can look remarkably similar in form. In Figure 4 below, I took the relations between actors and influencing factors from student-centered literature and fit them to the model developed above, demonstrating how instructor-side and student-side implementation could be portrayed in similar ways. Although there are certainly other models that could be developed, this one details the parallels that might exist between the two stakeholder perspectives.

Relational Framework

Environmental Factors

External (Outer-Context) Factors
Ex: Institutional Policy, Culture, Professional Competencies

Bridging Factors
Ex: Curriculum Requirements, Scheduling

Internal (Inner-Context) Factors
Ex: Support, Capability, Co-regulation, Course-level Factors

Prescriptive or Facilitative Influence

Emergent or Participatory Influence

Individual Factors

Fit with Needs and Preferences

Self-regulation, Motivation, Experience

Adopted Innovation

Adapted Innovation

Integrated Implementation

Performance and Outcomes
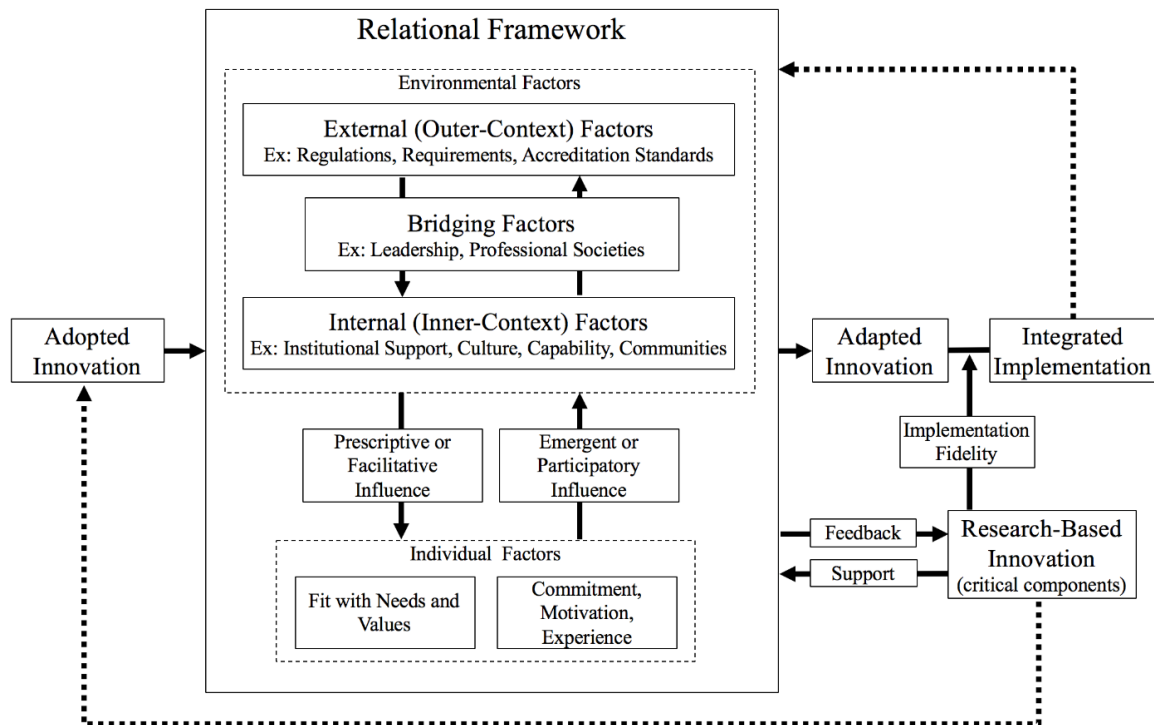
Feedback

Support

Instructional Framework (Learning Environment)

Figure 4: An initial model of student-side implementation of educational
innovations in higher education based on literature review

In traditional classrooms, we know that there is no be-all-and-end-all solution for how all students should study, as students' individual approaches to studying can, and should, be influenced by the course, its content, and the context of instruction (Wingate, 2006). This has also proven true in blended learning environments. Students have demonstrated a wide variety of different approaches to studying in blended learning with little-to-no effect on their course performance (Stites et al., 2020), and report adapting their approaches to learning based on course content, delivery, and assessment. In addition, students' own self-regulatory and co-regulatory behaviors have been shown to be key factors in promoting student success in Blended environments (Stacey & Gerbic, 2008; Zheng & Huang, 2016). Unfortunately, relatively little research has been conducted examining student's decision making related to resource use and self-regulation while studying in the blended learning context (Evenhouse et al., 2020). Modeling this behavior from an implementation perspective could help instructors to better understand, facilitate, and respect students' engagement with and use of learning innovations in higher education.

Exploring the Experience of Student-side Implementation

This new perspective on student-side implementation leads back to my original research questions. In the context of *Freeform*, we previously saw students making informed decisions regarding their use of learning resources and implementing educational innovations in individually unique ways (Evenhouse et al., 2020; Stites et al., 2020). Now, this literature review demonstrates two things: first, that there is support in broader literature for understanding and acknowledging students as independent decision-makers and implementors – especially within the context of blended learning, and second, that there is little research at present that ascribes students such a role in the context of pedagogical innovation. There are clear parallels between the process of facilitating implementations of innovations in higher education, and the process of facilitating student engagement with educational innovations in the context of their studies. Exploring the experiences of students as not only stakeholders, but as implementors themselves, could allow for new and valuable insights into how faculty, students, and the learning environment itself each relate to one another in the innovative classroom.

Characterizing what these relations might look like is an important first step. As is proposed in RQ1, this study intentionally examines the experiences of students as implementors in the context of the *Freeform* environment, elucidating how students enact implementation and proposing how those experiences might be categorized. However, even if we successfully characterize what these experiences may look like, there is a second concern. Although the findings of this study will be based on student interviews, the context in which those findings are understood and subsequently applied by readers may be based on extant instructor-centric conceptions of implementation and pedagogical change. Thus, RQ2 acknowledges that it is important to not only categorize and describe the experiences of student implementors, but to also present those experiences and their implications to readers in a way that is intentionally conscious of, and authentic to, the experiences of the students themselves.

METHODS

Addressing RQ1: Phenomenography

As part of this research, I am examining the ways in which students experience implementation in an innovative, research-based learning environment. I expect there to be a variety of ways in which implementation is experienced for two reasons. First, because our team has previously observed that *Freeform* students employ their innovative learning resources in a variety of ways (Stites et al., 2019), and second, because we have observed that the values and needs which students prioritize while studying can be vastly different from one student to another within the same context (Evenhouse et al., 2020). I also expect that, similarly to what we have seen through both thematic analysis and cluster analysis, we will be able to represent students' ways of experiencing implementation through some smaller subset of qualitatively different categorizations. Such categorizations would be useful as tools for the discussion and research of the implementation of innovations.

Considering our previous observations of the *Freeform* environment and the goals of my proposed Research Questions, phenomenography is uniquely suited to serve as a method of analysis in this study. Phenomenography examines, organizes, and categorizes how its participants actively relate to a given phenomenon. This sets the goal of phenomenography apart from the constructivist thematic analyses conducted in Freeform in the past, where we concentrated on participants' individual, personally constructed understandings and perceptions of a given phenomenon. It also sets phenomenography apart from phenomenology, which seeks to identify the singular essence of a phenomenon. While the unit of analysis is rooted in the language and conceptions of individuals, the main interest of the methodology lies in exploring and cataloguing the multifaceted nature of experience (Limberg, 2000; Marton & Pong, 2005), making Phenomenography a perfect tool for studying how students can relate to the *Freeform* environment and its resources.

Phenomenography also appears well suited to explore implementation as a topic of interest, as the philosophical and ontological assumptions inherent to phenomenography align well with the prevailing theories and models of implementation in literature. Just as phenomenography is concerned with the relations between people and phenomena (Limberg, 2000), implementation

theory models the relations between individuals, innovations, and their surrounding environments (Moullin et al., 2019). Relating students (as implementors) through their personal interactions with Freeform (as an implementation) requires using a method that intentionally examines and represents those relationships, making phenomenography well equipped to address RQ1 of this study.

Methodological Review of Phenomenography

Phenomenography is a methodological approach to studying the various ways in which a given phenomenon may be experienced by members of a human population (Limberg, 2000; Marton & Pong, 2005). This is done through the intentional examination of human experience and individual meaning making, often through the use of qualitative interviewing. Andretta (2007), who positions phenomenography as a tool for examining, understanding, and innovating higher education, references Marton & Booth (1997) by saying "…the unit of research is a way of experiencing a particular phenomenon, while the variation in ways of experiencing this phenomenon becomes the focus of the research." This focus on variation has proven useful for understanding the ways in which educational innovations have been employed (and thus experienced) in previous work, including investigations into the use of innovative learning technologies (Jones & Asensio, 2002; Englund, Olofsson, & Price, 2017) and pedagogical approaches (Koenen, Dochy, & Berghmans, 2015).

Phenomenography is distinct from many other research methods due to its governing ontological assumptions. Zygmont and Naidoo (2018) refer to phenomenography as having a non-dualistic relational ontology. Relational, in that it examines the relationship between individuals and the world around them. Non-dualistic, because rather than examining both the individuals and the world they interact with, phenomenography is interested in the *interaction,* or *relation*, between the two. This is referred to as the *subject-world relation* (Ashworth & Lucas, 2000), and it assumes that the subject and the world around them are never entirely separate from one another. Phenomenography assumes that the essence of how humanity experiences phenomena does not lie in the phenomenon itself, nor in one's perception of the phenomenon, but rather the essential interaction between people and the phenomenon of interest. This concept has also been referred to as *intentionality*: rather than examining one's perspective on a phenomenon, phenomenography

explores how and why its participants intentionally engaged with the phenomenon, and how that interaction defined subsequent conceptions of the phenomenon itself (Marton & Pong, 2005).

In a discussion highlighting the importance of variation in phenomenography, Pang (2003) asserts that "we can only discern what varies", indicating that the salient aspects of phenomena only become plain when people can experience them (and subsequently describe them) in different ways. Two thought experiments are presented as a means of explanation:

> "For instance, one would not be able to discern the aspect of gender should there be only one gender in the world; or the aspect of happiness should the Earth be filled with invariable happiness." (Pang, 2003: 150)

Phenomenography not only seeks to identify variations in experience, but further posits that salient aspects of a phenomenon of interest can *only* be observed when such experiential variations are present. While the communicated experiences of individuals may be the *unit of analysis* in phenomenography, the intentional observation and exploration of variation may be thought of as the *means of analysis* in phenomenography. For this reason, it is important to intentionally craft a sample of participants who could best maximize the observed variations in experience that are collected as part of the research process (Åkerlind, 2005b).

When conducting a phenomenography, we assume that there is some finite number of qualitatively distinct ways in which a phenomenon may be experienced (Marton, 1988). These distinct modes of experience are called *categories of description*; each category represents a way in which participants relate to the phenomenon of interest. These relations are described using key aspects of the phenomenon in which variations in experience were represented, referred to as *dimensions of variation*. These dimensions of variation are essentially a set of variables which describe important aspects of the subject-world relations being observed. Therefore, categories of description are nuanced representations of the various ways in which people might experience a phenomenon along its many dimensions of variation (Åkerlind, 2005b; Dall'Alba & Hasselgren, 1996; Limberg, 2000; Zygmont & Naidoo, 2018). In addition, categories should not be defined by one person's individual experiences (Pang, 2003; Zygmont & Naidoo, 2018). Select parts of various participants' experiences could contribute to the definition of multiple categories of description. Fully defining a single category on the reported experiences of a single participant could indicate that the analysis remains incomplete or that there is insufficient data for the study to reach saturation.

Categories of description are typically laid out according to a structure, progression, or hierarchy. Often, categories are arranged according to the expanding awareness they demonstrate regarding key aspects of the phenomenon, or the depth of reflection and investment demonstrated by participants' discussion of the phenomenon in question (Marton & Booth, 1997). This process of arranging the categories of description reflects the fact that Phenomenography does not only seek to identify different ways of experiencing a phenomenon, but also to understand how those findings might relate to, or interact with, one another. Thus, phenomenography not only relates the participants and the phenomenon, but also relates the categories of description to one-another (Zygmont & Naidoo, 2018; Marton & Pong, 2005) building a comprehensive picture of human experience. The findings of phenomenography may be tied to theory or to future study to further explain or explore the categories of description and examine their broader implications.

Phenomenography has been used to study the implementation of educational innovations in the past. For example, Koenen, Dochy, and Berghmans (2015) investigated the implementation of competence-based education at 26 different institutions of higher education. Their results produced four categories of description to label institutional implementations. Of special relevance to this study, the "role of the student" described in their final categories of description was different for each category, progressing from "mainly passive" to "mainly active". Although student experiences of implementation were not the focus of their work ("the role of the student" was only one of eight dimensions of variation present in their categorical definitions), the findings still speak to the ways in which implementation can manifest in students' learning experiences.

The Development of Phenomenography

Phenomenography was originally developed by researchers in higher education, specifically for use in higher education (Tight, 2016). Marton and Säljö (1976) first explored the method in their paper on students' demonstrated approaches to learning. The paper classified students' reported interactions with their learning material as seeking either a deep or a surface-level understanding of the topic being taught, a categorization which has gone on to broadly impact education theory (Marton & Booth, 1997; Webb, 1997). Building on their previous success, Marton further explored the potential of the method dubbed phenomenography to formally analyze and explore participants' different ways of experiencing reality (Marton, 1986, 1988), laying the groundwork for phenomenography and its contemporary methodology.

The growth, development, and popularization of phenomenography has not been a linear process. As a principally qualitative methodology, it has suffered from the same critical press related to academic rigor, subjectivity of findings, and lack of generalizability that has plagued qualitative research as a whole. In response to these concerns, key writers on phenomenography have placed an overt emphasis on its role as a complete and unified methodology, rather than presenting it only as a method of analysis (Dall'Alba & Hasselgren, 1996). This means that recent years have seen publications highlighting best practices in phenomenography related to data collection and participant selection (Åkerlind, 2005a; Dortins, 2002), interviewing (Bruce, 1994; Trigwell, 2000), the structuring of research (Ashworth & Lucas, 2000; Bowden, 2005), and the overall presentation of phenomenographic work (Marton & Booth, 1997; Sin, 2010); in addition to perennial publications on how to code and analyze data. Rigor has been largely pursued through the systematizing and normalizing of the methodology of phenomenography, ensuring that each part of the study, from formulation to conclusion, aligns with the ontological, epistemological, and philosophical assumptions that have been associated with phenomenography as a method of inquiry (Zygmont & Naidoo, 2018; Entwistle, 1997).

However, phenomenography has also been critiqued by qualitative purists for the opposite reason. While many researchers have addressed concerns related to rigor and generalizability in phenomenography (Richardson, 1999), other authors have critiqued the method for overemphasizing exactly those concerns (Hasselgren & Beach, 1996; Webb, 1997). Traditional phenomenography not only seeks to identify the ways in which a phenomenon is experienced, but also to impose an overarching structure upon those categories of description in order to derive findings that are both more meaningful, and more broadly applicable, than the categories of description alone (Svensson, 1997). This strict categorization and imposition on the data, some argue, is inappropriate for a methodology that claims to be inherently qualitative in nature. They argue that this approach may prevent both authors and audience from seeing the true range of variation inherent in human experience (Åkerlind, 2005b), and the ways in which such findings may be applied to practice (Pang, 2003); a condition which seems inappropriate for a method of analysis that specifically targets variations in experience.

My intention for this study is to produce findings that Mechanical Engineering instructors, and other practitioners in higher education, can use to better adopt and implement research-based innovations in their own classrooms. Although I plan to follow the methodological guidelines

presented in literature regarding the collection and analysis of phenomenographic data, I plan to further expand on the presentation of my findings to make them more easily accessible to engineering faculty. Engineering faculty often have a difficult time understanding and recognizing the importance of qualitative analysis (Borrego, 2007). To address this issue, which I acknowledged directly in RQ2, I have intentionally sought out ways to present my findings in an authentic and, hopefully, more easily accessible manner.

Addressing RQ2: Narrative Analysis

In addition to identifying and exploring the ways in which *Freeform* students experience implementation, I also want to present those findings in a way that is authentic to, and representative of, the experiences of the students themselves. In pursuing this, my goal is to demonstrate how the categories of description produced through phenomenography might be expressed (or further complicated) by the deeply personal and contextual experiences of student learners, allowing instructors to make informed educational design decisions that are both empathetic and contextually appropriate in nature (Barone & Eisner, 1997). To accomplish this, narrative analysis can be used to represent the experiences of my student participants within the trappings of a constructed, research-based narrative.

Narrative analysis enables authors to write research findings in a manner that is complex, human, and individually engaging. Just as experiences of the implementation process might develop or change over time, narratives can develop and change over time. This complex and storied presentation invites the audience to reflect on their own experiences and to draw their own conclusions about the phenomena being depicted. Bruner (1996) describes the interpretation of narratives as being "intransigently multiple", implying that one of the essential strengths of narrative work lies in its ability to be read, reflected upon, understood, and interpreted in a variety of different ways. There is a certain appropriateness in combining a method of analysis that seeks out variation, with a method of analysis that embodies variation in its presentation of results. For these reasons, narrative analysis appears to be uniquely suitable as a method of reorganizing and representing our understanding of students' various ways of experiencing implementation.

Methodological Review of Narrative Analysis

Narrative analysis, also referred to as narrative construction (Kim, 2016), is presented in Polkinghorne's seminal work as one of two branches of narrative inquiry (Polkinghorne, 1995). Much like thematic analysis produces themes, narrative analysis, according to Polkinghorne, produces narratives; the findings of narrative analysis are presented in the form of an intentionally crafted and emplotted story (or stories). Much like storyboarding is used in engineering to characterize consumers and model their interactions with products through story (Kimbell & Julier, 2012; Wikström & Verganti, 2013), narrative analysis represents the subjects and findings of qualitative research through narrative.

Narrative analysis in education is often described as an arts-based research method, meaning that it employs typically artistic or aesthetic elements as a functional heuristic in its research design. In their treatise on Arts-Based Education Research (ABER), Barone and Eisner (1997) note that:

> "…research texts often lack certain aesthetic design elements that work towards a powerful transmutation of feelings, thoughts, and images... Employing these design elements, ABER at its best is capable of persuading the percipient to see educational phenomena in new ways, and to entertain questions about them that might have otherwise been left unasked." (pg. 96)

To Barone and Eisner, the inclusion of artistic literary elements in narrative analysis is simply a result of form following function.

Both the purpose and methods of ABER align well with the content and inspiration of this study. The goal of an arts-based research project is not to convince the audience of a specific stance or to decisively support a specific hypothesis. Rather, its goal is to complicate, enhance, and deepen discussion by highlighting questions and perspectives that might have been overlooked, underappreciated, or otherwise taken for granted. This often happens through an intentional engagement with, and representation of, those stories and populations which may have been overlooked in previous dialogue or research (Barone & Eisner, 2012).

Being an arts-based method, narrative analysis can initially prove difficult for researchers to employ. As Barone (1996) writes, "no recipes or series of steps exist to guide the biographer, journalist, drama-tist, poet, novelist, or essayist inevitably to success" (pg. 143), highlighting the artistic and literary nature of narrative works. However, while studies employing narrative analysis do not have a single, governing methodology that must be strictly adhered to, there have been a

variety of frameworks developed to guide analysis and ensure quality in narrative work (Barone & Eisner, 2012; Kim, 2016). In contrast to phenomenography, writings regarding narrative analysis have largely chosen to eschew traditional conceptions of academic rigor in favor of more ambiguous, but no less taxing, qualitative conceptions of research quality. While many qualitative methods depend on the establishment of *trustworthiness* (Creswell & Miller, 2000; Collier-Reed, Ingerman, & Berglund, 2009), narrative work depends on the more fitting concept of *verisimilitude*. Narratives need not only to establish a rapport with the reader, allowing the reader to trust what is being said, but they must also present their research-based findings in a storied context that is understandable, authentic, and believable. Findings must not only be comprehensible, but also *relatable*. This is accomplished by presenting research that, when embedded within a narrative context, feels cognitively and emotionally real (Kim, 2016).

The generalizability of findings in narrative analysis does not depend on acontextual and axiomatic conclusions, but instead depends on the verisimilitude of the presented findings and the readers' ability to draw their own conclusions, questions, thoughts, and analogies from the stories they engage with. As a result, researchers who conduct narrative analysis must pay close attention to those elements and strategies of storytelling which make narrative works compelling to their readers (Coulter & Smith, 2009). For example, the following three elements of narrative will likely be necessary when presenting the storied experiences of student implementors.

Characters are actors whose experiences are told through story. Characters must be believable, relatable, and colloquial; reflecting the natures and values of the original participants (Kim, 2016). In addition, researchers need to take special care to ensure that none of the characters in the narratives they write demonstrate identifying traits or characteristics from their interview participants. They must be authentic to the student population, but not directly a part of the student population (Tolich, 2010).

Chronotope (literally meaning "Time-Space") refers to a story's ability to evidence change over time in a comprehensible manner (Kim, 2016). Although there is no inherent need to tell stories in a chronological order, characters do need to develop and progress as narratives run their course. Being situated in physical space, and developing as time passes, are essential parts of the human condition and thus, an essential aspect of our stories as well (Bemong et al., 2010). The ability of narrative inquiry methods to communicate information in a way that incorporates chronotope in a way that is relatable to its audience is one of its greatest strengths (Coulter & Smith,

2009). Chronotope empowers the researcher to communicate something dynamic, something living, rather than a series of cold and calculated conclusions.

Plot refers to the unifying progression or theme that ties the experiences of a character together, pushing them forward through time and inciting change. Plot allows stories to communicate information that goes beyond the sum of its parts; it acts as a narrative device which can both generate and demonstrate meaning. Plot is the backbone of story, relating disparate events to one another and providing the set of ideas, concepts, or goals that frame how and why characters develop (Polkinghorne, 1995).

This is why narrative analysis is referred to as an Arts-Based Research Method; the communication of both scholarly information and individual meaning is partially dependent on the artistic craft of the final research work. As Polkinghorne (1995) describes, "The story has to appeal to the reader's general sense of how and why humans respond and act", implying that works of narrative analysis should be judged not only in terms of research quality, but also in terms of their literary strengths: their verisimilitude.

The Development of Narrative Inquiry

Many researchers have struggled to find authentic and approachable methods to present the results of scientific inquiry. Since the late 1900's and the widespread proliferation of the post-paradigms (such as Postmodernism, Poststructuralism, etc.), academics have been discussing alternative approaches to communication and thinking in education and research (Usher & Edwards, 1994; van de Poel & Goldberg, 2010). Polkinghorne (1995) built on the previous writings of Bruner when he discussed the differences between paradigmatic and narrative cognitions, creating a guiding framework for many contemporary methods of narrative inquiry. *Paradigmatic cognition*, Polkinghorne elaborates, is how Bruner refers to a way of thinking that is primarily classificatory in nature. It is a traditional approach to generating knowledge that evaluates specific instances or cases to determine whether they could belong to a larger category or concept. Paradigmatic cognition allows for knowledge to be easily generalized between contexts that fall within the same category, but also tends to ignore the unique natures of each case and the complex relationships that can exist between categories. It compartmentalizes and breaks down information in order to better understand, clarify, or define key aspects of human experience. Bruner (1986) and Polkinghorne (1995) both argue that categorization is a very natural way for

humans to interact with the world. By recognizing and classifying our experiences, we can establish what is essentially a "comfort zone" of our known world. Rather than getting lost in the uniqueness of each of our individual experiences, we can recognize the categories and concepts which unite them, filtering our lives using a familiar, decontextualized, and personal understanding of existence. The analyses and findings of phenomenographic research, for example, are paradigmatic in nature, as they seek out connections and variations between the experiences of participants.

Narrative cognition, in contrast, may be thought of as the opposite of paradigmatic cognition. Where paradigmatic cognition operates by noticing similarities and categorizing along them, narrative cognition operates by highlighting the diversity and individuality in human experience. Through narrative cognition, knowledge about the world is tied to context and character. It is a form of knowledge that reflects humanity itself by being time-dependent, storied, relational, and deeply contextual. Bruner (1986, 1996) writes that narrative cognition is uniquely suited to understanding purposeful human actions and behaviors. Each case of human action is unique, influenced by past knowledge, present considerations, and individual goals or motivations. While paradigmatic knowledge is stored and communicated through the definitions of concepts or categories, Polkinghorne (1995) writes that, "…narrative knowledge is maintained in emplotted stories. Storied memories retain the complexity of the situation in which an action was undertaken and the emotional and motivational meaning connected with it." (pg. 11). By retaining this complexity through the use of story, narrative knowledge exemplifies human behaviors, allowing audience members to build an empathetic connection with the characters involved. Because of this storied presentation, the process of applying narrative knowledge to broader contexts requires careful judgement and use of analogy. Although not as easy to apply when compared to the categories and concepts of paradigmatic knowledge, narrative knowledge has the potential to communicate complex and profound insights regarding human experience to its readers (Huber et al., 2013).

In translating these forms of cognition into actual research methodologies Polkinghorne discusses two distinct branches of qualitative narrative inquiry. First, research which collects narratives as data and analyzes them to produce characterizations, classifications, or thematic descriptions of those narratives is called *Analysis of Narratives* (Polkinghorn, 2015, pg. 13-15). Narratives in this case are the subject of analysis, not the result of analysis, and paradigmatic

cognition is used to classify those narratives in useful or informative ways. In contrast, research which takes disparate data and analyzes them to produce a newly constructed narrative (or multiplicity of narratives) is called *Narrative Analysis* (pg. 15-21). The analysis process itself employs narrative cognition, which in turn produces narratives as a result. To quote Polkinghorne's work directly, "analysis of narratives moves from stories to common elements, and narrative analysis moves from elements to stories." (pg. 12).

Formalizing the use of narrative cognition in the academic space has been a long and arduous process. Narrative researchers have been quick to note that humanity has been learning, communicating, and recording knowledge in narrative forms throughout the course of our history (Kim, 2016). Telling and digesting stories in order to communicate deep understandings and emotional imperatives is not a new concept for humanity as a whole. However, storied understandings and analogical forms of research were largely absent from academic discourse until the late 1990's. This marked what is referred to as the "narrative turn" in the social sciences, a movement to incorporate and apply narrative cognition and narrative forms of knowing in formal research work (Czarniawska, 2004). Now, methods of narrative inquiry are seeing broad application in education and education research (Huber et al., 2013; Wolgemuth & Donohue, 2006), and have even made brief entries into the EER body of literature (Case & Light, 2014). As narrative inquiry has been introduced in the context of EER previously, it is worthwhile for us to review how it has been represented in previous publications, and what differences might exist between the methods used in this dissertation and those featured in prior studies in the field of EER.

The State of Narrative Inquiry in EER

First, I should note that the field of Engineering Education lies in a boundary space between multiple bodies of knowledge that have different definitions for the term "narrative analysis". Fields related to business and communication define narrative analysis as an entire genre of methods, both quantitative and qualitative, that are used to analyze, interpret, and draw meaning from narratives and storied data (Allen, 2017). Education on the other hand often refers to this overarching genre of methods as "narrative inquiry", in which narrative analysis is conceptualized as being one subset of narrative approaches which produce narratives as the result of research (Kim, 2016). However, even this definition is not universal within the field of education itself.

Clandinin & Huber (2010) for example, discuss narrative inquiry as being a specific, qualitative methodology in-and-of itself. This means that, depending on who you are reading and citing, "narrative analysis" and "narrative inquiry" could be referring to a variety of different methods or ideas.

This variation in terminology can lead to some confusion, and the field of EER has proven to be no exception to this rule. As narrative analysis has increased in popularity, various authors have taken different approaches to its introduction and explanation. The work of Case & Light (2011), in which the authors introduce narrative analysis as an emerging methodology in the field of EER, acts as an example of this. Alongside a direct invocation of Polkinghorne's (1995) explanation of narrative analysis, the article goes on to use the terms "narrative analysis", "narrative inquiry", and "narrative methodologies" interchangeably. Even the exemplar article is introduced as a study which uses a "narrative form of methodology" (pg. 205). In their later chapter for the *Cambridge Handbook of Engineering Education Research*, Case and Light (2014) continue this approach using "narrative analysis" and "narrative methodology" interchangeably, with no mention of "narrative inquiry". It is apparent then, that Case and Light use "narrative analysis" as a catch-all term for narrative methods, rather than as a subset of more specific narrative approaches.

A number of authors have adopted this approach as a result of Case and Light's work. For example, a recent article by Berdanier, Whitehair, Kirn, and Satterfield (2020) collected samples of written narratives from the social media site Reddit. The authors then analyzed those narratives using coding practices common to grounded theory research to develop themes characterizing those narratives and drawing insight, in this case, into engineering graduate students' stories of attrition. The authors cite Polkinghorne (1995) and report that they used a paradigmatic approach in their research: narratives were the subject of research, and their results are characterizations and themes derived from the analysis of those narratives. However, they also state that they are using narrative analysis as their methodology which, given that they are citing Polkinghorne (1995) and using his terminology, seems inconsistent. However, this inconsistency is explained by the authors' reference to Case and Light (2014). They are using narrative analysis as a general term for narrative methods at large and cite Polkinghorne to better explain their cognitive approach to the research.

We can contrast this with other works in the field of EER. Pawley and Phillips (2014), for example, reference Polkinghorne (2015) heavily to establish that their narrative analysis is intended to produce narratives (here in the form of case studies) as an *outcome* of their work. They echo the distinction between "analysis of narrative" and "narrative analysis", differentiating between the treatment of narratives as the *object* of research and the construction of narratives as the *result* of research. They go on to draw from multiple "methodological perspectives of narrative inquiry" (Pawley & Phillips, 2014, pg. 8), using "narrative inquiry" as a catch-all term for narrative methodologies in general. Kellam, Gerow, and Walther (2015) take a similar approach, using "narrative inquiry" as an overarching term and establishing the distinction between "analysis of narratives" and "narrative analysis" early in their paper. They also go on to adopt the term "narrative construction" or "constructed narrative analysis", to help their readers more easily distinguish between methods which construct narratives as an outcome of research, and those which analyze narratives as an object of research.

This all being said, I would like to reiterate that this confusion in terminology is not unique to EER literature. For example, at the time of writing this dissertation, searching Wikipedia for a quick introduction to "narrative analysis" will redirect the user to an article on "narrative inquiry", introducing the two terms as being essentially synonymous. Reviewing current literature in education will further show that some current scholars, in response to ambiguity in terminology across fields and Polkinghorne's somewhat confusing naming sense, have started employing the term "Narrative Construction" as an alternative to Polkinghorne's original use of "Narrative Analysis" (Kim, 2016).

Perhaps the most important factor separating these two approaches to narrative terminology in EER has been their publication venue. The works of Case & Light, as well as a number of studies referencing them, have appeared in venues with high prestige and visibility such as the *Cambridge Handbook of Engineering Education Research* and the *Journal of Engineering Education,* establishing their terminology as an early standard in the field. In contrast, those works that present narratives as the result of research appear almost exclusively as conference proceedings. Speaking practically, this may be a direct result of the continuing novelty of narrative analysis in the field of EER. Studies that examine narratives as the object of research use qualitative analysis methods (such as grounded theory and thematic analysis) that are already widely accepted and prevalent in EER publications, and thus can more easily seek publication in

well-established journals. In contrast, the construction of narratives in EER remains rare. It is not immediately apparent where such work would be published outside of a conference setting. Publication efforts are further complicated by the fact that narratives tend to have high word counts, and the broader implications of individual narratives are sometimes unclear. With all this in mind, pursuing publication of a constructed narrative in a flagship EER journal would likely prove to be an uphill battle, given the current state of the field. Not only are there few examples of narratives as the result of research in EER literature, those papers that discuss narrative construction in-depth are less likely to be published in well-known venues.

This is significant for the purpose of this dissertation, as I will not be following the terminology established by Case & Light (2014), but will rather be using the convention from education research in referring to narrative inquiry as an overarching range of methodologies that deal with storied information as subject, data, method, or analytical result (Kim, 2016). By citing Polkinghorne (1995) as the inspiration for my use of narrative analysis, I am directly invoking his definition of narrative analysis as a method. In a departure from previously published narrative analyses in EER (Marshall & Case, 2010; Berdanier, Whitehair, Kirn, & Satterfield, 2020), citing Polkinghorne (1995) here should demonstrate to my readers that I will use narrative analysis to produce narratives as a result of research, not to analyze narratives as a subject of research.

Narrative Cognition and Engineering Design Practice

In the context of this EER study, I believe that it is especially pertinent to mention that, although academic discussion of the "narrative turn" has been largely limited to the social sciences, there appears to have been a similar turn towards narrative cognition in the practice of engineering design in recent years. Engineering is a field that lies on the boundary between the "social sciences" and the "hard sciences", producing engineered artifacts for society through applied science and design methodology (van de Poel & Goldberg, 2010). Therefore, I think it should come as no surprise that engineering design has been experimenting with the use of narrative methods as a means of better understanding the needs of users and broader society.

With the growing popularity of human-centered design strategies (Boy, 2013; Kimbell, 2012) in recent years, methods that take a personal approach to understanding the interactions between people and products are becoming more widespread (Kimbell & Julier, 2012). Engineers have come to see the value in representing consumers and their potential interactions with

engineered products in an accurate, humanizing, and empathetic manner. Personas, for example, are fictional characters created through social research which act as complex characterizations of broad user-demographics. Designers use personas to better envision their end-users and the needs of their target market (Miaskiewicz & Kozar, 2011). As another example, storyboarding has become increasingly popular as a method to predict complex forms of user interaction with products during the design process (Kimbell & Julier, 2012; Wikström & Verganti, 2013). Storyboards are an embodied form of narrative cognition: they allow designers to think about and predict the actions of future users through use of constructed stories. Perhaps it should come as no surprise that Kimbell and Julier (2012) chose to call their collection of human-centered design strategies *The Social Design Methods Menu*, highlighting the socially-embedded nature of these contemporary design practices.

By framing design data in terms of who users are, what they need, and what can be done to address those needs, designers naturally convert a complex wealth of information into an easily digestible, narrative format. Many writers have already discussed the potential for similar narrative methods to transform (Huber et al., 2013) and inform (Johnson-Bailey, & Cervero, 1996) educational practice. By learning from the recent 'narrative turn' in engineering design, perhaps researchers in the field of Engineering Education can likewise use narrative methods to inform the design and evaluation of future educational innovations.

Methodology: Phenomenographic and Narrative Analysis

To address research questions proposed above, I intend to combine the established analytical methods of phenomenography with the postmodern approach of narrative analysis. This will intentionally blend a method focused on the categorical interpretation of paradigmatic cognition with a method of narrative cognition for the re-representation of findings. As a result, the final product of this work will be a phenomenographic and narrative analysis of student implementation processes, presenting the ways in which students experience their individual implementations of educational innovations through the use of both categorical definitions and emplotted stories. The final results will include separate sections covering the phenomenographic analysis, the results of that analysis, and the emplotting of students' experiences within research-based narratives. This follows in an existing tradition within ABER, wherein art-based research is

accompanied by supplementary non-art materials to help discuss and disambiguate the analysis and themes embedded in the works being presented (Barone & Eisner, 1997).

I believe that the phenomenographic and narrative analysis methodology described here is uniquely suited to address the research questions being proposed in this study. The two methods use different forms of cognition and hold different ontological assumptions, but each method examines human experience through the means of relations and variations. In addition, both phenomenography and narrative analysis are well matched with the core topic of research: the implementation of educational innovations. Through the combination of phenomenography and narrative analysis I hope to not only capture the variations in how individual students experience implementation, but to also represent the time-dependent and personal nature of those experiences in an authentic and academically rigorous manner.

In their discussion of ABER and its ability to support and encourage empathetic understanding, Barone and Eisner (1997) comment, "In this kind of research process the author acutely observes and documents telling details of human (educational) activity. Varied perspectives on the meaning of these activities are not merely stated and explained, but, as is the case with good art, expressed and enhanced." The aesthetic and literary approach of narrative analysis specializes in expressing and advancing varied perspectives on experiential meaning, while Phenomenography specializes in the formal and analytical identification of peoples' varied perspectives on experiential meaning. Narrative analysis promotes narrative cognition and incites reflection and change (Wolgemuth & Donohue, 2006) while phenomenography is more paradigmatic, encouraging rigor and broader impact through methodological means (Zygmont & Naidoo, 2018). By combining these two methods this study will be able to engage with participants and readers alike in ways that could not be demonstrated otherwise.

The methods used for this study are intended to combine practices from phenomenography and narrative analysis in ways that minimize conflict and maximize mutual benefit between the two research approaches. Of the two, narrative analysis is much more open to adjustment and reinterpretation, meaning that the majority of the methods discussed below (especially those related to participant selection and data collection) will more closely follow the dictates of phenomenography.

Participant Selection

Phenomenography and narrative analysis traditionally have different requirements for participant selection. The number of participants required for a narrative analysis depends on the topic of study, and what story the author is seeking to tell. Narratives could represent the experience of an individual, or attempt to represent an entire subculture. Some narrative works may even be autobiographical, in which the sole participants are the authors themselves (Kim, 2016). Phenomenography, when approached from a perspective valuing rigor and generalizability, looks for saturation of the data (Bowden & Walsh, 2000) or for a scope of participants that captures all expected variation (Green & Bowden, 2009; Sin, 2010) typically requiring between 25-30 participant interviews (Green & Bowden, 2009).

Although we have already seen that both the individual and environmental factors that influence implementation can be highly complex, there are some assumptions that can be made regarding the variation of students' implementation experiences in the *Freeform* environment. Previous works have identified variation in student performance based on declared major, prerequisite course performance, and residency status (DeBoer et al., 2016b; Stites et al., 2020), as well as some slight differences in predicted resource usage based on residency status (Stites et al., 2020). In addition, based on our prior research and broader literature review, students' own experiences with blended learning and educational technology can help to inform and direct their future use of similar innovations (Evenhouse, 2018a). It is important to note that course performance should not be considered as a true proxy for student experience, as students' course performance and their perceptions of implemented innovations do not always correlate (Zhu & Engels 2013). However, the combination of these factors should capture a broader range of possible variations in students' implementation experiences in the *Freeform* environment than a simple random sample would allow.

An initial pilot of the participant selection process (two rounds of invitations sent to groups of 24 purposefully sampled students) held prior to the Spring 2020 semester demonstrated that approximately 1 in 12 students who were invited volunteered as participants in the interview process. These students were sampled based on their prior participation and performance in blended ME courses, their residency status, and their declared major. In light of this pilot, 144 students in *Freeform* dynamics (listed as ME 274 in the PUWL course catalogue) were selected and invited to participate in this study immediately prior to the start of the Spring 2020 semester.

Students were selected based on the same criteria as the pilot, and all were invited by email. This process targeted a minimum of 12 total participants, ideally distributed among the targeted demographic variables, as shown in Table 2. This targeted minimum of 12 participants would yield a total of 48 interviews after the planned four rounds of interviewing.

Table 2: Ideal distribution of 12 participants across targeted variables.

12 students	ME Major	Non-ME Major	ME 270 Registered	ME 270 N/A	ME 200 Registered	ME 200 N/A
Resident/Non-Resident	3	3	3	3	3	3
Foreign/International	3	3	3	3	3	3

In total, 16 students volunteered and participated in the interview process. Again, all participants were invited by email, and were offered $25 as compensation for their participation in each interview. Students were also offered an additional $25, contingent on their completion of all four rounds. Thus, student participants could receive a maximum of $125 for their participation in the study.

Although I had expected some participants to drop out of the interview process partway through the study, the rise of COVID-19 in the USA and the subsequent closing of campus at PUWL had a significant impact on student participation. Campus closed between the 2nd and 3rd rounds of interviewing, and the resulting complications led to half of the participants exiting the study. Table 3 below breaks down the 16 original participants based on the study's target demographics. Table 4 then breaks down the remaining eight post-COVID participants based on those same criteria.

Table 3: Distribution of participants across targeted variables during 1st and 2nd round interviews.

Rounds 1 and 2 16 students	ME Major	Non-ME Major	ME 270 Registered	ME 270 N/A	ME 200 Registered	ME 200 N/A
Resident/Non-Resident	6	4	8	2	6	4
Foreign/International	3	3	6	0	4	2

Table 4: Distribution of participants across targeted variables during 3rd and 4th interviews.

Rounds 3 and 4 8 students	ME Major	Non-ME Major	ME 270 Registered	ME 270 N/A	ME 200 Registered	ME 200 N/A
Resident/Non-Resident	3	2	4	1	1	4
Foreign/International	1	2	3	0	1	2

I should note that very few of the students had not taken any blended courses prior to their entrance into ME 274. This is because ME 270: Basic Mechanics I (Statics), is a direct prerequisite for ME 274: Basic Mechanics II (Dynamics) at PUWL, and ME 270 (Statics) is blended using the same *Freeform* learning environment as ME 274 (Dynamics). Only students who were enrolled in, or had transferred from, majors outside of Mechanical Engineering had a chance of taking ME 274 (Dynamics) without having taken ME 270 (Statics). In my original sample, only two of the 16 students had not taken Statics due to transferring between programs or institutions in the previous year. After the switch to remote learning, only one participant remained who had not taken ME 270.

Data Collection

The primary source of data for this study was individual interviews with participants. Interviews are one of many possible sources of data that may be used in a phenomenographic study. Marton and others have discussed communication (both spoken and written) (Bruce 1994; Marton, 1988; Trigwell, 2000), observations of behavior (Marton 1988, Rogers et al., 2007), and physical artifacts (Marton, 1988, Tamm & Granqvist, 1995) as possible sources of data for analysis. However, interviews continue to be a standard practice in qualitative data collection as they allow for free and open discussion on the part of the participants, follow-up questions to foster reflection or clarification, and the opportunity to develop comfortable rapport between the interviewee and the researcher (Ashworth & Lucas, 2000; Dortins, 2002). Interviews create a functional balance for the participants and researchers, being less time consuming and intrusive than direct observations, but still allowing researchers to collect detailed data on the participant's experiences and perceptions of the phenomenon of interest. They are especially well-suited for phenomenography due to its express focus on the participants' own descriptions of their experiences: interviews are flexible, allowing the data collection process to spend more time on

understanding the words of the participants rather than relying on the observations or assumptions of the researcher (Kinnunen & Simon, 2012).

Interviews for phenomenography examine the variations in participants' experiences and perceptions of a phenomenon of interest. As implementation is the phenomenon of interest, and implementation is a process which takes time to develop and complete, this study employs multiple interviews at different points throughout the semester. These points were chosen based on findings from prior qualitative analysis of the Freeform environment (Evenhouse et al., 2018a; Evenhouse et al., 2020) as well as literature on implementation and adaptation (Koenen, Dochy, & Berghmans, 2015; Taylor et al., 2018b). For example, I was sure to include a round of interviewing during the first three weeks of the semester, as well as another round just after the first three weeks. Students and an instructor in a previous study (Evenhouse et al., 2018a) had noted that their first three weeks served as an initial period of transition, after which the semester started to feel 'normal' again.

Interviewing for narrative analysis serves a slightly different purpose than interviewing for phenomenography. Although narrative analysis also investigates the relationships between people and their experiences, the goal is not expressly to tease out variation from the data. Rather, it is to uncover a wholistic representation of the participants, their experiences, and the story that binds them together. Interviews for narrative analysis seek out two things: the components of a compelling narrative, and an authentic understanding of how that narrative has played out in the lives of the participants. For this reason, narrative studies will often employ active interviewing methods (Holstein & Gubrium, 2003; Wolgemuth & Donohue, 2006) which seek to socially construct knowledge alongside the interviewee throughout the data collection process. Active interviewing provides space for complex storytelling, as participants are encouraged to explore new perspectives, insights, and meanings as they reflect on their own lived experiences.

All this having been said, the data collection processes for phenomenography and narrative analysis do not appear incompatible. Both examine the relationships between participants, their environments, and key points of interest. Likewise, both take time and effort to examine what kind of meaning or broader implications their interviewees have drawn from their past experiences. Each search for subtle factors which might influence or impact the participant's perspective, and then intentionally explore the participant's understanding of those factors. Therefore, my goal for the data collection in this study was to develop a single interview protocol could address the needs

of both phenomenography and narrative analysis. The final interview protocol may be found in Appendix A.

In general, when conducting qualitative interviewing for data collection it is imperative that the researcher takes time to ensure the quality and integrity of the interview process. In reality, it may be impossible for researchers to entirely bracket their individual assumptions when going into an interview process (Ashworth & Lucas, 2000; Fischer, 2009). Despite this, there are still a number of steps which researchers can take to encourage clear, honest, and authentic data collection. First, interviewers should take care not to ask questions which assume some sort of experience or behavior on the part of their participants (Åkerlind, 2005a). For example, asking a student "How has your experience changed in the past few weeks?" assumes that the student has experienced a change. If you instead ask, "Have you experienced any changes in the past few weeks?" you allow for the possibility that the student has not noticed any changes. Regardless of whether the student reports experiencing a change or not, you can then use follow-up questions based on their responses to further clarify their personal perspective.

As a researcher, it is also important to avoid projecting your own understandings of certain words, concepts, or ideas onto the reported experiences of your participants. Different communities have different ways of expressing their ideas (Guldberg & Mackness, 2009), and there is no guarantee that your participants' use of certain words or phrases will align with your understanding of those same ideas. This is why *intentional-expression* has become an important practice in qualitative interviewing. Whenever participants bring up a new concept or idea, the interviewer should take time to confirm and clarify what the participant means by describing that concept in greater detail (Sin, 2010). This process of clarification not only encourages the development of richer, more in-depth descriptions of the topic of interest, but also ensures that the research process understands and respects the individual experiences of its participants. It may also serve as an active interviewing method, helping students to build a rich and in-depth understanding of the topic of interest during the interview itself (Wolgemuth & Donohue, 2006).

Unfortunately, qualitative interview processes can sometimes be unsettling. Although many participants in phenomenographic studies report participation in interviews to be a positive experience (Bruce, 1994), there is always a risk that interviews may touch on topics that are sensitive or uncomfortable to the participant. Reminding interviewees that the research process is always voluntary and can be ended at any moment is an important step in ensuring the safety of

interviewees, but it is not always enough. That is why many interviewers employ the practice of *free-association*. In an interview using free-association, the initial interview questions are kept very broad, and the interviewer's follow-up questions do not introduce new concepts or topics that the interviewee has not previously discussed. This method ensures that the interviewer does not touch on topics that the interviewee is not comfortable bringing up themselves, allowing the interview to develop in a natural and comfortable manner. Although the data produced by this method may not be as well targeted as data from a more structured interview protocol, it allows for a much more participant-driven data collection approach (Åkerlind, 2005a).

The interview protocol that I am proposing for this study of student implementation considers the needs of both phenomenography and narrative analysis, characterizing student experiences of implementation throughout the semester while positioning those experiences within a rich and personal context. The protocol includes opportunities for four interviews per participant during the semester of interest as outlined in Table 5 below. Interviews should typically last between 30 and 45 minutes. A full copy of the protocol may be found in Appendix 1.

Table 5: Interview process breakdown.

Interview Instance	Governing Topics
Interview 1 Weeks 1-3	Personal Description Educational Background Expectations and Motivations
Interview 2 Weeks 4-6	Initial Transition Sense of Belonging Initial Routine
Interview 3 Weeks 9-12	Engagement with Freeform Experience of Freeform Current Implementation
Interview 4 Weeks 15-17	Reflections on Freeform Meaning Making Moments of Experience

Previous protocols used in the *Freeform* environment were designed to ask about course elements and resources directly. While this was useful for getting targeted feedback at the start of the *Freeform* project, using associative and reflective methods will allow us to better understand

how this course and its resources might affect and interact with the personal experiences of the student participants. Unlike previous data collection methods, these interviews better speak to how students' perspectives and experiences of the course environment can change over time. Employing a less constrictive and more reflective interview protocol could allow this study to obtain more natural, unfiltered information on the student experience.

Data Analysis

Initial data analysis began simultaneously with interviewing. To start, each interview was followed by summary and analytical memo writing (Kim, 2016; Creswell, 2012), with additional rounds of iterative reflection and analytical memoing occurring after each round of interviewing. This served two purposes: first, to maintain a constant awareness and familiarization with the results of each interview, and second, to begin the process of searching for similarities and variations in the participants' experiences. As such, after writing the initial summary of each interview, the majority of this analytical memoing was *comparative* in nature, rather than interpretive, taking the reported experiences and meaning-making of each participant and juxtaposing them with the experiences of their peers, or with their own experiences described in earlier interviews (Creswell, 2012).

Analytical memoing contributed to the analysis and findings of both the phenomenography and the narrative analysis, but took on a different role for each methodological approach. Phenomenography looks for representative examples and variations in experience, iteratively returning to the data to clarify categories and dimensions of variation (Zygmont & Naidoo, 2018). Narrative analysis looks for key moments of development and similarities in experience, teasing out possible storylines through in-depth and repeated engagements with participants' stories (Kim, 2016; Polkinghorne, 1995). One seeks individual experiences, while the other seeks to draw disparate experiences together. One categorizes based on variation, while the other forms characters based on similarity. Therefore, it was very rare that a single round of memoing could make a substantial contribution to the findings of both methods simultaneously. Instead, repeated iterations of analytical memoing had to be conducted focusing on either variation, or similarity, in turns. Likewise, each method necessitated that I take a different approach to the further analysis of my data (and memos) as I worked towards the identification of my findings.

Phenomenographic Analysis

The process of searching for categories of description and their constituent dimensions of variation began after the conclusion of the second round of interviewing, following a round of analytical memoing searching for variations in participants' reported experiences. After the second round, many students were already reporting that they had "found a routine" for the semester, and were able to describe a variety of initial implementation experiences. Because of this, the process of tentatively categorizing experiences began at that point – halfway through the data collection process – and was largely based on students' initial transitions into the Spring semester. After the third round, and in light of an entirely new assortment of implementation experiences on account of Purdue's switch to remote learning, the fledgling categories of description were slightly altered and extensively defined through the identification of more representative experiences and delineating dimensions of variation as students repeatedly compared their early experiences of implementation to those they had underwent in light of COVID-19. The fourth round of interviewing brought in data that further clarified both the categories of description, and how those categories might be related to one another, solidifying the findings in light of additional representative experiences and the students' own reflections on their past semester. These initial findings were then repeatedly revisited and critically examined in light of the participants' interview transcripts, ensuring the representative experiences that had been identified and the categories they represented were well-supported in the dataset.

In summary, there were three major rounds of iterative phenomenographic analysis during the semester, each shaped by the introduction of additional data and clarifying comments on the part of the students themselves. These rounds occurred in conjunction with analytical memoing, which served to repeatedly question both the data being collected, and the findings being developed. After data collection was complete, I went through additional iterations of in-depth analysis, refamiliarizing myself with the dataset as a whole and comparing my initial findings to the representative student experiences that had been identified, the content of students' own reflections on the semester, and the content of my analytical memos that had developed with each round of interviewing.

In their overview of phenomenographic analysis, Zygmont and Naidoo (2018) emphasize the importance of questioning one's own analytical assumptions by advising that researchers, "Oscillate between devil's advocate and interpretation promoter roles" (pg. 11) as they search for

weaknesses in the analysis and its findings. In my final round of analysis, I applied this concept both generally, and literally, resulting not only in more analytical memos but also in a series of self-prompted question-and-answer sessions to help me wrestle with my analysis and the interpretation of my prior results. For example, one such question-and-answer focused on the implications of remote-learning in the participants' experiences:

> Q: Is the model's focus on individual circumstances unfairly influenced by the individuality of experience introduced by the switch to online learning?

The purpose of each question was to interrupt and complicate my analytical process or my developing results. The goal as I wrote each response was to produce a comprehensive answer based off my data and ongoing analysis. If this was not possible, or if trying to answer only led me to more questions, it necessitated a revision to my developing categories of description or a return to the data for additional analysis. During analysis, my initial answer to the question above highlighted the *circumstantial* vs *environmental* aspects of the participants' experiences of implementation, reinforcing my own understanding of how context contributed to the phenomenon of interest. This went on to shape a large portion of my findings and the interpretation of my results. Other questions targeted topics such as the definitions of specific categories of description, biases regarding the definition of implementation, previous findings from the *Freeform* environment, and how specific pedagogical innovations might interact with my developing results.

In bringing up previous findings from the *Freeform* environment I should note that I was not concerned with determining the fidelity or relative effectiveness of individual students' implementations of *Freeform* and its components. Regardless of whether or not students chose to engage with all active, blended, or collaborative elements of the class, their discussions still reflected their personal experiences of implementation and the sense-making that had occurred since that time. As Marton (1986) states directly, "phenomenography is also interested in mistaken conceptions of reality" (pg. 32). It does not matter whether the meaning that participants draw from an experience is fundamentally correct or not. Rather, misconceptions (or in this case, misguided implementations) are still representative of the participants' experiences of the phenomenon in question. Even if *Freeform* instructors are concerned with ensuring that their students are applying their resources correctly, those concerns would not lead to the exclusion of any data from phenomenographic analysis.

Narrative Analysis

The process of memoing, thematically analyzing, and subsequently constructing representative narratives from multiple participant interviews is what Mishler (1995) describes in his typology of narrative inquiry as "Imposing a Told on the Telling". This phrase implies that the researcher examines data collected from their many participants (examining what the participants are *telling* the interviewer) in order to identify possible storylines through which to construct a narrative addressing some predetermined theme (the story to be *told*, in this case student experiences of *Freeform* implementation). By identifying unifying characteristics, salient experiences, and meaningful storylines the goal is create a narrative (or a series of narratives) that represent the implementation experiences of students in an accurate and empathetic manner.

Polkinghorne's approach to understanding and utilizing narratives in research is referred to as *Diachronic Organization*, in which the term diachronic emphasizes the importance of how experiences, and stories of experiences, change and develop over time (Polkinghorne, 1995; Kim, 2016). In contrast to the phenomenographic approach to analysis, which revolves around the identification and comparison of participants' singularly representative experiences of a phenomenon, a diachronic narrative perspective attempts to examine and represent experiences as being embedded within an ongoing and evolving story. Whereas individual interviewees describing single experiences could be described as synchronic (as in, occurring at a single point in time), a perspective that demonstrates the development of experience using background information and contextual description could be described as diachronic (experiences occurring over multiple points or periods of time).

In light of the need to examine possible storylines and the importance of respecting the time-dependent nature of implementation, analysis regarding the identification, construction, and organization of plot elements did not begin until after the second round of interviewing. This allowed for comparison between rounds to identify how implementation experiences might have developed as the semester progressed. Questions on each participants' learning background during round one also helped to establish a chronology of events, enriching and broadening the scope of the students' developing narratives. I began experimenting with writing characters, constructing plots, and establishing chronologies soon after concluding the third round of interviewing, partially as the result of an independent writing project. The switch to remote learning, and the stark view of students' experiences afforded by my ongoing interview process, led me to write a brief

document describing students' transitions from on-campus to remote learning. The themes I developed through this process were included in a brief article published in the ASEE *Connections* e-newsletter (Evenhouse, 2020), and in identifying those themes I began the process of combining traits and stringing together experiences into a cohesive series of narratives. This writing project gave me a unique opportunity to collect advice and editorial feedback from members of the *Freeform* research team, informing my analysis and writing processes. Also as a result of this writing project (and as a result the students' own experiences), the switch to online learning became an integral part of each representative narrative, often serving as the *complicating action* driving each individual plotline forward (Mishler, 1995).

The characters and plot elements used in this study were not finalized until after the fourth round of interviewing, at which point the participants were able to reflect upon and describe the semester as a whole, pulling together possible storylines of their own accord. Dialogue was written while referencing the transcripts of those interviewees who inspired each character, with the goal of preserving their voices and some of their colloquial speech patterns to foster additional verisimilitude (Tolich, 2010). In addition, I took care during the narrative analysis process to respect the ontological assumptions and governing philosophies of phenomenography when possible. For example, while narrative analysis can build upon the story of a single character or participant, phenomenography cannot. It is not enough for a phenomenography to simply conclude that "different people experience phenomena in different ways" and present each participant as a distinct experiential variation (Åkerlind, 2005a). Variations are represented by different categories of description, and those categories must represent something more than simple individuals. In turn, any narrative analysis produced in conjunction with the findings of a phenomenography should not be a simple retelling of one participant's experiences. Narratives that are used in-part to represent variations in experience should depict characters that are distinct from, but still inspired by, the individual participants whose perspectives have contributed to those findings.

In an intentional nod to the sequential nature of the four rounds of interviewing conducted in this study, the resulting narratives have taken on a similarly sequential format. The story of each character is told in a series of three to five brief narrative entries, reflecting the snapshots of insight provided by the interviews and reflecting the limitations of the data collection process through the structure of the narratives themselves. The narrative entries have also been combined into a single product and arranged chronologically, forcing the reader to rapidly shift between the stories of

each character as time passes in the context of their narratives. This was also a deliberate decision, and reflects the same process of repeated engagement, disengagement, and analysis that I took part in during my sequential rounds of interviewing – a process which Kim (2016) describes as *flirting* with the data. In this way, the actual structuring of my narrative findings was as much inspired by my own experience as a researcher as it was by my student participants. It is my hope that readers who encounter these narratives will read them with an open and analytical mind, drawing their own observations and conclusions from the situations being described.

Impact of COVID-19

The arrival and spread of COVID-19 in the Spring semester of 2020 had an immense impact on the day-to-day working lives of people across the nation. This study, and its participants, were certainly not exempt from the effects of the global pandemic. I have already mentioned how the switch to remote learning coincided with a sharp drop in interview participation, but there are other ways in which the effects of COVID-19 can be observed in this study and in the reported experiences of its participants.

Implications for the Data Collection Process

The most obvious impact of COVID-19 on this study was a sharp drop in participation. Although having 16 total participants was close to typically recommended values for phenomenographic work (about 20 or more individual interviews, see: Zygmont & Naidoo, 2018) especially considering the multiple rounds of interviews, eight participants is well below any typical benchmarks. Yet, despite participation dropping by 50% after the switch to remote learning, the distribution of students across the target demographics remained remarkably consistent. The exception to this was a sharp decrease in the proportion of students who had previously taken ME 200 (Thermodynamics) and experienced its blended resources. However, having a higher number of participants who did *not* previously take ME 200 may have been beneficial to the goal of maximizing possible variations in the interview content. My original sampling strategy aimed to include a large number of students who had little prior experience in blended learning environments. As only 1 out of the 8 participants in the third and fourth rounds of interviewing had not previously taken ME 270 – Statics, having a large number of students who

did not take ME 200 may help to mitigate the effects of students' prior blended learning experience on the implementation experiences observed in this study. This is, of course, speculation, and the loss of participation was certainly not beneficial in-and-of itself. However, bearing in mind the goal of this study (to describe and represent various student implementation experiences), I consider having a population with less overall prior blended experience to be preferable to a population with more overall prior experience. Lower participation limits the scope of this study, but the implications of losing 50% of the original participants could have been much worse.

The changes that COVID-19 necessitated to my data collection processes, particularly to the topics covered by the third and to a lesser extent fourth rounds of interviewing, are somewhat less obvious. Due to the intense disruptions caused by COVID-19, students were forced to go through new periods of transition and subsequent normalization that echoed those that were described at the start of the semester. Therefore, many questions from the first and second rounds of interviewing were reused during the third and fourth rounds. Table 6 below makes a general comparison between the interview topics I had expected to cover during each round of interviewing, and how those topics changed after the switch to remote learning to capture new experiences of implementation in new contexts.

Table 6: Interview topic comparison before and after the effects of COVID

Interview Instance	Pre-COVID Topics	Post-COVID Topics
Interview 1 Weeks 1-3	Personal Description Educational Background Expectations and Motivations	Personal Description Educational Background Expectations and Motivations
Interview 2 Weeks 4-6	Initial Transition Sense of Belonging Initial Routine	Initial Transition Sense of Belonging Initial Routine
Interview 3 Weeks 9-12	Engagement with Freeform Experience of Freeform Current Implementation	**Expectations and Motivations** **Initial Transition** Engagement with Freeform
Interview 4 Weeks 15-17	Reflections on Freeform Meaning Making Moments of Experience	**Current Implementation** **Sense of Belonging** Reflections on Freeform

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Thankfully, these changes led to some positive outcomes for the purpose of this study. The switch to online learning forced students to go through new periods of transition partway through the semester. As a result, this disruption effectively increased the number of implementation-relevant experiences that students were able to share. While there were fewer participants in the third and fourth rounds of interviewing, the data collected was far richer and more applicable to the research topic than could have been expected otherwise. Taking into account my 16 original participants and eight continuing participants, the interview process as a whole explored 24 (16+8) instances of student transitions and, often as a result, a comparable number of implementation experiences.

Implications for the Analysis of Student Experience

While student participants were able to share a new range of implementation experiences after the switch to remote learning, the context in which those experiences occurred was very different from those discussed in earlier interviews. Most of the participants moved back into their parents' homes between the second and third round of interviewing, and learning moved from being blended to taking place entirely online. Students simultaneously lost much of their independence by moving back home, saw their sources of interactive support disappear when they left their campus community, and were thrust into a social climate filled with stress and anxiety due to a global pandemic (Evenhouse, 2020). Yes, students still had to transition into a new learning environment and, in the process, go through new experiences of implementation. However, those experiences were influenced by a range of factors that were absent from the students' environment earlier in the semester, necessitating a change in how I went on to conceptualize and analyze those experiences for the purpose of this study.

To help in understanding and identifying experiential variation, Marton and Booth (1997) describe the experience of phenomena as having two sets of structural, related characteristics termed the *internal horizon* and the *external horizon*. The internal horizon refers to the salient aspects of the *specific instance* of the phenomenon being experienced, while the external horizon refers to salient aspects of the *context* in which the phenomenon occurs. For example, the use of different learning resources would likely present students with different internal horizons of the experience of implementation, as the resources may contain different content or may be accessed in differing ways. In contrast, using the same resource in different courses would present students

with different external horizons, as each course will likely have different curricular requirements for their students to meet, and or may use the same resources to address different topics.

The effects of COVID-19 resulted in concrete changes to both the internal and external horizons of the students' learning experiences. With regards to the internal horizon, students saw not only a change in the resources that they were able to use (such as losing access to the TA help room), they also saw a change in how their resources could be accessed (such as watching asynchronous lecture videos, rather than attending synchronous class sessions). Students were also forced to accommodate a variety of resources that could now only be accessed through the use of their computers or phones, limiting the ways in which they could access and interact with their various sources of help.

One of the most important themes to develop after the switch to online learning was its unanticipated effects on students' external motivations for learning (Evenhouse, 2020). In fact, the pandemic's effects on students' motivation were likely much more dramatic than could captured by my interviews (but may be partially represented by the study's drop out rate), and not just due to the societal stressors introduced by the pandemic itself. I mention in the article for *Connections* that students' loss of community caused by the closing of Purdue's campus not only inhibited their ability to engage in collaborative learning, but also served to cut off many of their external sources of motivation that stemmed from the campus context. Students who would previously work ahead in order free their weekends for social activity found it difficult to keep up their routine without their community to act as a motivator. Likewise, students who regularly attended lectures with their friends lost that source of peer accountability once lectures changed to a video format.

Of special significance to this study, the forced adoption of online learning constituted a major departure from any of the students' prior learning experiences, regardless of their previous registration in ME 270 (Statics) or ME 200 (Thermodynamics). Although some students had engaged in online learning before the pandemic, especially during previous summer semesters, none described going through such an extensive and all-inclusive disruption of their learning experience and established routines. In some ways, the disruptions cause by COVID-19 acted as a great equalizer. Although students still had individually distinct learning experiences after going to online learning, the switch acted to ensure that all students would need to go through new experiences of transition, implementation, and normalization. Even if the students had taken ME 270 (Statics) and thus had prior experience working with *Freeform*, no student had experienced

Freeform in this new, online context. While some students could say at the beginning of the semester that their routines just "felt like normal", those students who continued to participate beyond round 2 all had significant moments of experience to discuss as they acclimatized to their new learning environment.

The ability to directly contrast new experiences of transition with those which occurred at the start of the semester added further value to these later rounds of interviewing, disambiguating key aspects of students' experiences and fostering reflection on the part of the interviewees. In the end I believe that, strictly in the context of data-collection concerning implementation, this study saw an overall benefit as a result of the disruption due to COVID-19. This is reflected in the widespread presence of data from the later rounds of interviewing in the content of the results presented below. However, the applicability of the conclusions of this study are no longer so clear as they could have been. What started as a straightforward examination of student experiences in blended learning now addresses a mix of blended and fully-online learning environments. Although the switch to online learning led to the further definition and disambiguation of my results, it also necessitates that readers take more care in taking those results and applying them to their own engineering instruction or research.

RESULTS

Phenomenographic Findings

The Outcome Space

In phenomenography, research findings may be depicted in the form of an outcome space: a structural model showing not only the categorically different ways in which participants experienced a phenomenon, but also depicting the ways in which those categorizes might relate to one another. The final categories of description developed as a result of this phenomenography are summarized in Table 6 and presented in the form of a model in Figure 5 on the following page. It is important to keep in mind that phenomenography examines participants' experiences of a phenomenon: it is not a direct examination or representation of the phenomenon itself, nor of the participants themselves (Bowden & Walsh, 2000). Therefore, *these categories of description are not a means of categorizing students.* Nor do they comprise a model of implementation in their own right. Rather, this outcome space characterizes students' experiences of interacting (or not interacting) with specific resources or educational innovations. Students in blended learning environments (or in online learning environments) can encounter a wide range of educational resources and can thus be experiencing multiple processes of implementation simultaneously, each potentially falling into different categories of description in the model in Figure 5. For example, a given student who has many transformative interactions with educational innovations in their coursework could also be cut-off from interacting with specific resources due to circumstances beyond their control. Such a student would evidence implementation experiences that fall into both the first (Circumstantial Non-Adoptive), and last (Transformative), categories of description listed in Table 6.
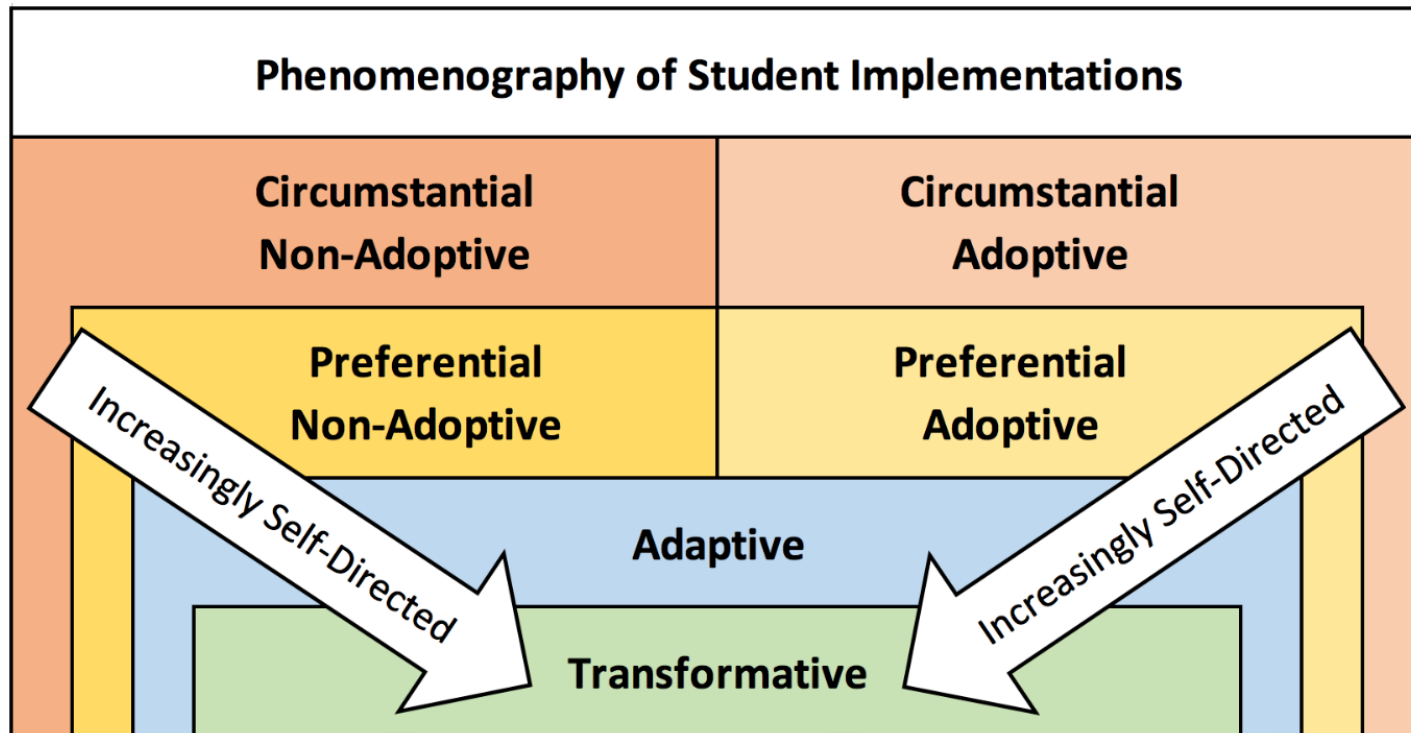
Figure 5: The phenomenographic outcome space: a hierarchical model of student experiences of implementation.

Table 7: Phenomenographic categories of description, their definitions, and representative examples.

Category Title	Description	Examples
Circumstantial Non-Adoptive	Students do not have the opportunity to implement innovations due to circumstances beyond their ability to control.	Class schedules conflicting with office hours, no access to required technology, lack of awareness, prevented due to disability.
Circumstantial Adoptive	Students comply with the circumstances of their course, participating in activities and implementing resources as required.	Attending class because attendance is graded, engaging in collaboration only during required class activities.
Preferential Non-Adoptive	Students choose not to use resources or engage in learning activities on account of their personal preferences.	Choosing not to use the lecturebook due to a preference for taking notes on a tablet, preference to work and study alone.
Preferential Adoptive	Students choose to engage in learning activities and incorporate available resources as part of their existing study habits and routines.	Checking for posts on the blog when in need of help, choosing to watch solution videos to help with studying, using the lecturebook in class.
Adaptive	Students alter their habits and routines to better address their own educational needs using new activities and learning resources.	Students completing homework in the help room, working ahead to post questions on the blog well in advance.
Transformative	Students develop a better understanding of their own learning needs through engaging with or implementing specific activities or resources.	Discovering the value of collaboration through the discussion forums, learning the importance of repetition through video lectures.

Explanations of the Categories of Description

Circumstantial Non-Adoptive

Circumstantial Non-Adoptive describes students' experiences when they are unable to implement certain course resources or innovative learning methods due to circumstances that are beyond their control. Their experience of "implementation" in this case is generally a frustrating one. Students who are unable to employ learning resources due to environmental, temporal, and physical barriers typically feel that they are being disadvantaged in comparison to other students; that they are being denied access to resources that may otherwise have proven useful in their studies.

For example, many students reported difficulty finding time to attend office hours or making time to go to the tutorial help room due to scheduling conflicts. Tutorial room hours and office hours tend to follow a weekly schedule that is not widely known to students prior to the start of the semester. Students whose course schedules were filled with classes in the early afternoon found themselves unable to attend the tutorial room for any significant period of time. Likewise, students whose courses coincidentally conflicted with their instructor office hours felt they could not readily use their instructor as a source of help.

Student 1 discussed his scheduling conflicts extensively during our second-round interview. He had recently changed majors, and the majority of his friends from ME had already taken Dynamics. As a collaborative learner, Student 1 felt he would have benefitted from being able to attend the TA tutorial help sessions, but his schedule stood in the way:

> "I feel like my biggest issue is, a lot of times on the homework for all of my classes, I guess, sometimes it's hard for me to get started alone… I need to utilize the help rooms and stuff, but they're all during the week, and they all kind of conflict with my own schedule and stuff like that, or with one another. I'm getting to the point where I've realized, I need to start getting a lot more of my work taken care of on the weekends. In order that I'm not so crammed during the week. But sometimes it's hard to get certain assignments done if I can't go in and get help. You know?
>
> I mean, I'm starting to get better about it, but sometimes it's hard. Especially when I need help. If I'm unable to go to the help room, and I'm stuck, it's kind of like I'm bogged down. Like, I can't get anywhere with it, you know?"
>
> – Student 1, Round 2

Of course, scheduling was not the only barrier to implementation that students encountered. Resources that require interactions among multiple people likewise require engagement from

multiple people. Said another way, if their peers are not willing to participate, students will not be able to use their peers as a learning resource. Student 2 discussed an awkward in-class experience in which she seemed to be excluded from an opportunity for peer collaboration:

> "so [the prof is] like, 'Yeah work with two or three people around you', whatever, whatever. And the kid that walked in late, he turns to the guy on the other side of him and he's like, 'Hey, do you mind working with me on the quiz?', and the guy's like, 'Sure, no problem'. And I was like cool. And then the guys on the other side of me, they all walked in together, so I knew they were all friends with each other and were going to work together.
>
> So I was like, I have no one to work with on this quiz. And I'm like that's okay. And so I looked at the quiz. I'm like okay, I know this. Do what I have to do.
>
> – Student 2, Round 1

Students can also be turned away from resources when the use or presentation of the resource itself is problematic. In the third-round, Student 3 highlighted two different examples of this. First, he noted that students' misuse of online collaborative resources turned him away from them, making asynchronous online collaboration unavailable as a source of help:

> "I guess in some classes, there's like a Piazza wall or a blog. I don't use it all that much because in the class I have it in, it's mostly just used to complain about the class."
>
> – Student 3, Round 3

In addition, he discussed the instructor's use of technology for recording lectures, and how the switch to online learning often precluded the instructor from being available as an interactive learning resource. During lecture, this came through in the students' inability to ask clarifying and supporting questions in-class.

> "…that's become even more important than I ever thought, [the] quality of handwriting, which you think is this little side note, but when you can't ask questions about what that symbol is, it's really, really important.
>
> Once again, in [a different] class, [the instructor] has a really terrible camera that we can't really tell what [they're] writing. And the difference between I and capital Phi are very small if you can't see the little circle. So yeah, it can be really confusing.

… like, [they] like to write off the screen without noticing to the point where [they're] still talking a mile a minute and we can't even see what's going on, which in class isn't annoying but in online learning, you actually miss things. You can't just ask for it… It seems like such a minor thing, but it's frustrating and it creates those inconsistencies that don't need to be there."

– Student 3, Round 3

Student 4 mentioned a similar inability to interact with their instructor, but extended this to settings beyond the scope of online lecturing.

"...in a traditional environment, when you have a question, it's pretty easy to just ask the question, then you will either - you'll get an answer. You'll get a response. So, it's a pretty simple, good system. Whereas now, being in this isolated position, if you have a question, the burden's on you to find the answer. It's much more difficult to be able to... it's almost easier for you to find the answer than it is to find the way to ask it, if that makes sense."

 – Student 4, Round 3

Of course, students can only report Circumstantial Non-adoptive experiences when they are themselves aware of the resource they were prevented from adopting. Interestingly, Student 5 discussed a non-adoptive experience from the previous semester that he had been unaware of at the time. Statics courses at PUWL use the same online solution videos that Dynamics courses do. Student 5 had taken Statics during the previous semester, never realizing that there were solution videos available as a learning resource.

"There were a lot of times in Statics where we'd get a homework problem that was just like one in the book, but they hadn't gone over that one in class, so I didn't have the example. I'd feel like, they'd only have the solutions to 'this' and I just, didn't realize they had 'that' on the web page. But I figured that out this semester. So it's been especially helpful."

– Student 5, Round 2

"I'd make sure [my friends who take this course in the future] know about the solutions to all the examples in the book. They have all those online. Those were definitely a huge help."

– Student 5, Round 4

Prior research in the *Freeform* environment has shown that students often have very positive views concerning resources that they personally did not have the chance to use (Evenhouse et al., 2020). This category of description further clarifies those prior findings. There is a sense of futility,

or inevitability, in many student discussions of these experiences as many of the barriers they encounter arise, at least in part, due to their own prior decisions. It is also interesting to note that a *lack of access*, and a *lack of information*, act on the student experience in much the same way. Both act as a restriction preventing an assumed adoption with students expressing positive perceptions of the resource either way, despite their own lack of engagement.

Circumstantial Adoptive

Circumstantial Adoptive describes students' experiences with resources and innovations that are prescribed by their instructor or institution. This generally includes mandatory in-class learning activities, events and activities with assessments targeting students' participation or attendance, or innovations that that can only be utilized in a limited number of ways. Taking attendance or giving graded quizzes during class, for example, can force students to adopt certain learning behaviors related to attending lecture. Grading participation in group work can enforce adoption of collaborative learning behaviors, and making students download and submit homework using an LMS or third-party application can force students to use more digital technologies or to do homework in an environment where they have access to requisite devices, such as scanners or school computers.

Student 6, for example, described themselves consistently throughout the semester as being a very individual learner. They prefer not to engage with aural or collaborative resources, instead prioritizing self-directed and individual learning opportunities. Student 6 stated outright that he would prefer not to attend every lecture in Dynamics but continues to do so because of the in-class assessments.

> "I go to every class in case there's a quiz, but I find it very difficult to learn from someone just speaking. When I'm listening to people, I have acquired a short attention span.
>
> So, I normally don't learn much at all from classes, at least not when we have the textbook. So in, say in thermo which I'm doing right now, the topics are in one place and the book is somewhere else. And also the topics are so new and complicated that I manage to keep my attention for that hour and then basically just take notes and learn the topic. But in terms of Dynamics, I know enough of it to not pay attention."
>
> – Student 6, Round 1

This kind of discontent with obligatory attendance seemed to be a common theme. Student 12 contrasted lecture attendance in his early coursework with students' modern ability to teach themselves at home and online.

> "… professors don't always explain things very well, and that can be very discouraging. That's why a lot of kids just don't go to class, because class isn't always helpful. With certain classes, of course, like the big lectures and whatnot, they would just rather learn it online via Khan Academy or on their own or something.
>
> …And then the one professor mandates you bring an iClicker to class, and then everyone hates that professor because you're forcing us to be here, but you're not teaching us anything. And that's just a bad situation for everyone."
>
> – Student 12, Round 2

However, instructors are not the only actors who can exert circumstantial pressure to reinforce adoptive behavior. Building on Student 6's discussion of in-class assessments, peer accountability also came up repeatedly as an environmental motivator for attending lecture. Student 1 mentioned this in terms of his courses beyond Dynamics, where he has peers who attend the same lectures that he does.

> "I mean, I don't want to go sometimes, but I have classes with the guys that I work with. So that's kind of accountability, just to make sure we go."
>
> – Student 1, Round 2

Student 2, who was repeating Dynamics, brought her friend up as a similarly motivating influence. Participating in lecture with her friend and helping him to learn motivated her to attend class, even during the first few weeks of review at the start of the semester.

> "I like the fact that one of my good friends is in it, we've been friends since my freshmen year. He didn't know until this year that he had to take it…Which is nice because I can help teach him stuff, which brings back what I know already. And it holds me accountable to actually going to class because as soon as we're still at the beginning and I took this course last semester, it's really easy to be like, 'I don't want to do this because I know what he's going to say. I know this, I know that.'
>
> So I still go to class and I'll sit there and actually do the homework while I'm in class because at least I'm still working on dynamics and I'm doing what is coinciding with what he's lecturing on. And if there is some sort of nuance that I did forget, I can listen in at the same time."
>
> – Student 2, Round 2

Of course, mutual accountability among peers did not show up as a circumstantial motivator for students who preferred to work alone. In fact, Student 6 said that they would prefer to avoid collaborative work entirely, and only engaged with their peers when required to do so as a part of the course or its assessments.

> "I don't talk to anyone in that class at all. I'm very, I guess you can say independent in terms of that. In terms of my school, I don't like to collaborate with anyone. If it's a group project I'm taking leads, I'm organizing the group and I'm managing time… I had extremely high ratings all throughout and very nice reports from the other [students] because I really put myself into it and I put my standard and projected it onto others. And I think in many times that helps.
>
> But if it's an individual assignment, I do it myself because I don't trust anyone to do the work."
>
> – Student 6, Round 2

Finally, circumstantial pressures were very beneficial for students. Student 5 discussed this in two separate contexts during our fourth-round interview. First, he reflected on how peer accountability helped him to maintain a healthy homework schedule while on campus, and second, he mentioned how not having a synchronous lecture time allowed him to procrastinate more easily.

> "I had to go to the class. I guess the structure of that, and that you have to go to the class or you're going to miss the lecture – there won't be a video you can go to later on. Something that keeps you accountable to watch the lectures... That's what helped me, I think. At least when I'm on campus.
>
> …I'd have friends come over most evenings at Purdue [before COVID] so I'd try to finish my work before 5. But then I wasn't starting it until like 6PM when I was at home, just because there wasn't much going on. So I was like, 'Might as well do my work at night, I guess.' Maybe that was my mindset. I don't know. Or I was just pushing it back. Yeah, definitely having stuff going on made me finish my work earlier."
>
> – Student 5, Round 4

Students who were highly self-motivated, were skilled in time management, and who had extensive experience in self-directed learning tended to resent Circumstantial Adoptive experiences. On the other hand, Student 5 benefitted from circumstantial pressures, and had difficulty imposing a schedule on himself after the switch to online learning.

Preferential Non-Adoptive

In Preferential experiences, we see students start to exercise an active control over their own use, or non-use, of study and learning resources. Whereas Circumstantial categories could be thought of as prescribed implementations governed by the instructor or other external forces beyond the students' control, here we can start to clearly see the students' own values, ideas, and preferences evidenced through their actions.

Preferential Non-Adoptive experiences of implementation are characterized by an intentional rejection of encountered pedagogies, innovations, and resources. In the experiences of the student participants interviewed here at PUWL, these experiences were frequently represented as the result of a rational, decision-making process on the part of the students themselves. Rather than a gut reaction or an instinctual resistance to change, these non-adoptive experiences were presented by students as an intentional exercise in metacognitive learning practice based on preconceived notions of what works, and what doesn't work, in their own educational experiences.

In the Circumstantial Adoptive category, one can encounter stories of students who were forced to go against their metacognitive understanding of their own learning due to circumstances beyond their control. In direct contrast, Preferential Non-adoptive experiences are characterized by students' ability to reject and avoid such situations. Returning to Student 6, the self-described independent learner from earlier, the outbreak of COVID-19 and subsequent switch to online learning afforded them a unique opportunity to translate their learning preferences into actual practice. After lectures switched to a video format, Student 6 decided to forgo lectures completely and instead learn directly from the textbook and homework assignments.

> "I just sit down with my book and work through. I think one of my academic gifts is that I learn from the homework and when I figure out the homework, I also learn the topics. So I can just sit down, like yesterday, Monday, I sat down with the homework for Dynamics. I looked at it and I looked at the book and then I did the question. And I didn't know the topic when I came in."

– Student 6, Round 3

Student 6 was not the only student to forgo watching lecture videos after the switch to online learning: several other students were able to give similarly thoughtful reasoning to justify their non-adoption of video lectures. Student 8, for example, discussed using their textbook to teach themselves content for one of their courses.

"You couldn't really skip lectures in physics because they have iClicker attendance stuff. But honestly, I didn't really get much out of a lecture when I did go, so now I read. It takes so long, but I read the book to learn and I don't really watch the video lectures they post. Don't sue me. And that's been working fine. So, that's like the only class that's really been a change. And it's a change that I probably would have implemented anyway if I didn't have to go to lecture, and that took up time I could have been using to read the book anyway... In that class only because there was such a disconnect between the lecture and the lab and the recitation, because it was like I was more overwhelmed about what was going on rather than actually learning anything. So reading the book kind of glues it all together."

– Student 8, Round 3

Of course, entirely rejecting the use of lectures is something of an extreme case for the Preferential Non-adoptive category. More often, students discussed the merits and demerits of specific resources and sources of help, explaining their study habits and routines in justification of their non-adoptive behavior. For example, when Student 4 noticed an increase in participation on the course discussion forums after the switch to online learning, he reviewed the content on the blog and determined it wouldn't be useful for him as a source of help.

"So, I've definitely seen people using [the discussion forums] more but it's usually not... usually, it's very specific questions, is what I found. At least, for me, where I struggle is not in the specifics as much. I guess, it's the... I guess, the overview. Like, okay, I understand what the problem is and if you just give me a little push – for example, you've got a disc problem and someone says, 'Think of how would you look at the kinetic energy of your disc,' then I'm good, then I can solve the problem all the way."

– Student 4, Round 3

Others described similar experiences of non-adoption while classes were still taking place on campus. Student 7, for example, would often stay on-campus during the afternoon to finish homework before going home. He felt he was more productive in a campus environment than he could be in his living space. However, despite working near the TA tutorial rooms and at times when the tutorial rooms would be open, he never bothered to attend.

"I can't function or do homework in my room. To be in my room is basically like a sacred place. I go there to sleep, to chill, to do nothing basically. So I do homework, everything, study outside. Basically stay out all day. So yeah, I do homework outside of my dorm all the time.

…Yeah, I do have time [to go to the tutorial room]. And I don't know if I've gone. No, I've gone to the ECE one, but tutorial rooms… I haven't had so much of a problem that I needed to go there. I could understand what my friend was doing, or I can understand it by using the book. I didn't have to go to the tutorial room."

– Student 7, Round 2

Perhaps the starkest example of Preferential Non-adoptive experiences came from students who decided not to use the *Freeform* lecturebook. Developers have previously described the lecturebook as the core of the *Freeform* learning environment (Rhoads et al., 2014), and previous research has shown that the lecturebook is the most widely-used learning resource among students in *Freeform* Dynamics courses (Stites et al., 2019). Although use of the lecturebook is not required, it is highly encouraged. Much of the in-class instruction draws heavily from the lecturebook's content, and the solution videos available online are designed to match with in-text examples. Therefore, students who choose not to use the lecturebook are truly breaking from the norm. Two of the interview participants reported choosing not to use the lecturebook, and each could provide a reason for their decision.

Student 3 reported a personal preference for taking notes on his tablet. He felt that this process was more beneficial for his learning, and allowed him to easily transfer and share his notes among his various devices or friends.

"I do it on my computer actually. I write them on the screen. And actually, I like that. I know he prefers us to do it in the lecturebook, but I feel like if I'm drawing the pictures, I'm taking in more of what's going on.

And, if I can make a quick and dirty sketch as he's demoing or explaining the problem, get everything lined up, get all the omegas and alphas and all that figured out, I know exactly what's going on better than if I were to just use the printed one and start doing the math immediately. So, I like doing that and I'm going to definitely stick with that method. It's been working so far. It takes a little bit longer, but I think it's worth it."

– Student 3, Round 2

Student 3 also reported that his situation was exacerbated by a physical condition. Using a tablet allowed him to easily take digital pictures of the board when he was unable to keep up with the pace of the lecture.

"And actually, a weird thing I have too, is I have this eye condition where I usually have spots that float around. So, for me to transition from writing to looking is a total pain because I have to look up and then there's this little thing that floats around. So I have to focus, let it settle, and then read the board. So, it's usually a couple seconds before I can actually see, which is a pain.

It's something I've had for years. My eye doctor said it might go away, it might not. He said, 'Your brain might tune it out.' So, maybe my brain's not smart enough to tune the thing out, but it's just, funny. So, it makes it frustrating when I lose the spot visually and then I have to look back up and you're like, 'Oh, here we go…'

– Student 3, Round 2

In contrast, Student 9 reported that they preferred not to take notes at all. They had no difficulty in staying focused and attentive during lecture, and needing to look down to take notes served as more of a distraction than a long-term benefit. Student 9 would rather pay strict attention to the lecture during class in order to better learn the content, and then use supplementary materials outside of class to reinforce their learning or to study for exams.

"I mean, it's probably just me, I can't concentrate on the lecture itself while taking very good notes. So, I would put understanding the material as my priority, and take some essential or like, basic notes that – it's not like a full copy of what the instructor did. But like, after I saw the instructor, I saw the instructor's notes, I try to understand it first. And then I find if there is something that inspired me, or if there's something that I can come up with. Then I would write it down, mostly as a reference. I don't really look a lot at notes…

…especially for this course, because for all the lecture examples you have the video solutions on the course website. So, for me, I would try to use the lecture time to understand the material instead of having some notes, I guess. That's so – I don't want to take notes and go home and study later. I want to figure it out right there during the lecture. And if not, like after the lecture, I will go and see the instructor."

– Student 9, Round 4

Preferential Adoptive

The Preferential Adoptive category is characterized by student's intentional engagement with, and use of, given learning innovations in a manner that is already personally familiar, perceived as valuable, and easy to employ. To clarify: while the innovations or resources may be new, the ways and contexts in which they are used are commensurate with students' prior studying and learning experiences. The resources readily fit with the study habits, preferences, and routines

that students have previously built up over time. Therefore, these students do not have to go out of their way to accommodate or engage with the resources they choose to employ.

I suspect that the vast majority of student experiences (in the *Freeform* environment) that touch on the implementation of innovations and resources fall into the Preferential Adoptive space. However, this is based more on my interpretation of student interviews and less on specific, highlighted examples. The ease and familiarity with which students engage with their new resources likely means that these Adoptive experiences did not stand out as being particularly novel or innovative. As these engagement behaviors could fit into students' regular practices and familiar routines, the participants did not examine or reflect on these experiences until directly asked about them in the context of our interviews. The use of comparisons between resources and the in-depth examination of periods of transition proved to be especially helpful in eliciting discussion of students' preferred forms of learning.

For example, one quote from Student 8 (used in the section above) demonstrated her decision to stop watching the lecture videos for one of her courses. After that quote, she then went on to describe the lectures in her Dynamics course, highlighting why those lectures fit better with her learning preferences.

> "…with [Dynamics], at least my professor, I don't know if it's the same for everybody, but even if he's reading through the pre-typed stuff that's like the theory behind it or whatever, he'll highlight certain things and underline and explain what the equations mean and stuff. And then there'll obviously be examples that start with just the problem statement, and he'll hand-write the solution so I can follow along and write at my own pace instead of just looking at words or a picture and either trying to scramble to write it all down or just looking at it and not really getting it."
>
> – Student 8, Round 3

Student 7 made a similar comparison, comparing the lecture videos from one course which he did not utilize with the lecture videos from Dynamics.

> "Well, [my other course] has lecture [videos], but they're very shallow, I think. They don't go in very much depth, and they do one example for an entire topic and things like that. So it's not that helpful. It's helpful a bit, but I don't think it's as helpful as Dynamics, which has all the videos and things like that. Various examples of it.
>
> … So I didn't watch those, but those are available if I wanted to use them."
>
> – Student 7, Round 3

Student 10 made a comparison between collaborative resources before and after the switch to online learning. When discussing the role of the online discussion forums he highlighted how much he preferred to simply text his peers when he had specific questions on the homework, rather than posting to the forum and waiting for a response.

> "…just because you get more of a prompt response I guess. And it's easier if you get a notification on your phone. I'm sure if, yeah, the blog had something like that then I would definitely consider using it more.
>
> I think I mentioned in the previous interview that there would be certain people who would just finish the work ahead of time and I could discuss it with them…
>
> …That's my general strategy in school. Just find two or three people who are more reliable I guess, and stick with them for the entire semester."
>
> – Student 10, Round 4

Student 4, who was a very collaborative learner while on campus, expressed a strong preference for discussion forums after the switch to online learning. They helped him to maintain a sense of normality as he had frequently used short, incidental interactions while on campus to get help on homework and clarify his understanding.

> "It also is nice, because there's the [discussion] forum to ask questions. So the homework questions, you can put up there, and it's easy because the entire community is there to be able to ask questions. So a lot of the time, if I have a question, most likely its already been answered: someone else has had the same question. Or, if I have a question, it's usually answered pretty quick by somebody that's either done it, or knows what's going on. I guess, that's what I would say the best example is, of keeping to the pretty much normal schedule, but also having a really good forum to discuss what's going on, the questions and such."
>
> – Student 4, Round 3

In contrast, Student 3 maintained his own sense of normality by texting the same people he had worked with while on campus, rather than using the online forums.

> "…really, I usually just rely on people I used to talk with questions like, I'll shoot a text over someone that I used to sit down and do the homework with and we'll cross-compare. So, that works similarly. It's just rather than running down the problems, it's texting out why I did this and that and the other thing. So, it's pretty similar, I guess, you could say in that regard."
>
> – Student 3, Round 3

This normality is key to the Preferential Adoptive category, reflecting a resource's fit with the students' predetermined needs and prior learning experiences. Students did not go out of their way or change their study practices to engage with resources that did not have some additional, or enhanced, perceived value for their learning. Access and availability are key parts of these implementation experiences. It was not until highly valued resources were made unavailable or inaccessible that students started to adjust, or for the purpose of this paper *adapt*, their learning strategies in response.

Adaptive

Adaptive implementation experiences are characterized by concrete changes in student behavior that allow for the accommodation of additional opportunities for learning and resource engagement. Students' experiences of Adaptive implementation show them going out of their way, or outside their prior experience, to engage with specific resources and innovations. This can be contrasted with Preferential Adoptive experiences, which are characterized by the use of easily accessible learning resources in personally familiar ways.

Participants in this study reported adaptive experiences that were self-motivated, made in response to circumstantial pressures, or driven by some combination of the two. Students who reported experiencing adaptive implementations usually sought out and facilitated the use of resources that they perceived to be especially useful or effective for their study needs. Student 3, for example, discussed how he adapted his studying after the switch to online learning. He had mentioned previously that being unable to interact with the professor was a severe disadvantage inherent to online lecturing. To compensate, he began to heavily utilize the online solution videos to build up his understanding and confidence.

> "I can watch the lecture over breakfast, which I don't usually find gets super deep. It'll just be explaining how or why the lecturebook says a certain formula, where it comes from, how to use it…
>
> …usually what I'll try and do is if there's two or three examples on whatever the last one is, I'll try and do it out, and then go ahead and re-watch it and make sure I did it right and that kind of thing. So I found that to be a really good way just to try and build up that confidence like I would in class."
>
> – Student 3, Round 3

As another example, Student 11 reported that she had always been a primarily collaborative learner. She had built up a small study group with her friends in the previous semester, and that group had slowly expanded over time. After the start of the Spring semester their study group grew extremely quickly, going from their original few members to nearly 30 people at the time of our second-round interview. This rapid change in group dynamics both forced her, and empowered her, to change her routines and study habits.

> "Well, I think in my last interview or whatever I mentioned my study group that I have. We utilize that a lot, and just have people work together, not necessarily even have to be working on the same thing. But it's just calming to be around, I don't know, other people working at 1:00 in the morning.
>
> … it's kind of crazy because last semester it started out with [a small group of people] and we got [more joining in]… now we have 27 people in the group chat, which is a little intimidating, but they're all very nice… And now there's like three people whenever you go to the atrium.
>
> … We have like two tables in the atrium that we can fill with people that now know each other and work together. So it's kind of cool. Yeah, I think I like it a lot.
>
> … So I know always, whenever I'm on campus and have free time, I just go back to ME to work. So, go upstairs, and some of them are there, so we can work on dynamics. And that's just worked well."
>
> – Student 11, Round 2

Also related to collaborative learning, Student 8 reported adapting her existing study group so that they could all keep working together after the switch to online learning. This required a large number of students to go through individual processes of adaptation, and their efforts appeared to pay off.

> "Well, we used to meet in [the Bechtel building] every week and work on stuff. So we were all like, 'We still need this help from each other. We're not going to just be able to do it alone, especially without a lecture and the in-person, hands-on labs.' So it was just a smoother transition.
>
> I think some of them didn't have Discord [for online communication]. Me and my nerdy self had it. But yeah, I think some people; I don't really know who didn't have it, but I know some people weren't as Discord-savvy. But it wasn't that hard.
>
> But the five of us really do, we have calls every week to talk about our homework and our labs. So we still do kind of do our thing…"
>
> – Student 8, Round 3

It is also worth pointing out that adaptive experiences could arise from students' own proactive changes to their learning process, not just as reactions to outside disruptions. Student 5 reported going through a process of adaptation at the start of the Spring semester that was entirely premeditated. These changes were motivated by his own poor performance in the Fall: in an effort to improve his grades he looked up study skills on the internet over Christmas break, reflected on his prior study behaviors, and came to campus with a plan of action to fix his GPA.

> "I think I realized it's only going to get harder from here. I mean, nothing's gonna get easier, so I think you've got to make the change now instead of later.
>
> …I thought about most of the changes over Christmas break. I knew that I couldn't keep doing the same thing. I looked at what was available for the classes I was going to take. I know that thermodynamics and regular dynamics has tutorial rooms that you can go to, plus office hours. Physics, well actually thermodynamics now also has supplemental instruction sessions. So I just tried to figure out where I was going wrong last semester and how to fix that this semester.
>
> I actually spend less time in my room working because I found that I focus better when I'm at a library or something working. And then I go to tutorial rooms and stuff like the one for dynamics. Just trying to change it up.
>
> …I mean, I feel better. I remember when first exams came last semester, I just didn't understand the concepts I was learning at that point. I definitely feel like I understand them more."
>
> – Student 5, Round 2

Student 5 was not the only student entering into the second semester of their Sophomore year looking to make changes in their learning process. Students 4 and 12 reported similar experiences, citing poor performance on both exams and final grades during the previous semester. Student 9 seemed to go through a similar experience as a result of the Spring semester, describing his own motivation for future growth during our fourth-round interview.

> "…like math and Dynamics, they do require me to be better in order to success [sic]. It's like my current ability, the ability that I currently have… I'm not already competent to get an A in this course. I need to improve. I need to learn more. I need to build up more ability, or I need to have more clues, or better techniques, in terms of learning, and in terms of like introspection on myself to be able to success [sic].

And as I said, I do enjoy this process, because I know I'm doing a meaningful thing. I know I'm getting better. No matter what grade I have I'm getting better as the result – as the takeaway from this course. So, that's why I say I do enjoy it. Like, in other words, I enjoy improving myself."

– Student 9, Round 4

Transformative

Transformative experiences of implementation are distinguished from adaptive experiences by the lessons which students learn about their own learning, and their potential for inspiring lasting changes in student's learning behaviors. Rather than just exercising their pre-existing understanding of how to learn, students in transformative implementation experiences learn something new about their own learning processes or preferences as a result of their interaction, or sometimes lack of interaction, with specific innovations and resources. Transformative experiences often grow out of adaptive experiences, facilitated by students' own reflections on learning and iterative changes to their own study habits.

For example, Student 3 built on his adaptive experience of employing the online solution videos to express something profound about his own learning. By combining his prior educational experiences with the adaptations he made in light of COVID-19, he discovered a new approach to learning that he hadn't considered before.

"Actually, back in high school even, I remember teachers, especially my Math teacher who was awesome. He's one of the best. His strategy was that we do a lot of examples in class, but he'd always do ones where we'd have to do it ourselves. He'd give us like two or three minutes, and we come back and try it, and that was helpful.

…I found a lot of times, especially just in college in general, there's not a lot of in-class time to really test yourself. It's all about absorbing. And sometimes if I don't feel like I am testing my knowledge, it might go away and I have to go find it again. So, that's been nice to have a little more time to do that and take my own time, read along, do the problem, and check it. So, I like that strategy.

…to be fair, I'd never actually used [the solution videos] before. I felt bad, but I didn't really feel I needed to just because I liked the stuff and it came [to me] pretty well. But now that [videos are] all there is, [the solution videos are] super helpful. And I probably would have [used them] before. Maybe not all of them, but definitely one-a-day or something just to see more examples. It's super helpful."

– Student 3, Round 3

As mentioned above, Student 5 began his Spring semester with a number of adaptations already in mind. By engaging with his learning resources in new ways, and by reflecting on those experiences throughout the semester, Student 5 gained insight into his own learning process. His understanding of scheduling and repetition, and of how they contributed to his own learning, became especially important as he engaged with homework and lectures.

> "… I don't feel like there's constantly work on me. It's just, I try to do the work for when it's assigned instead of when it's due. …if you do it on Monday or Tuesday, then you can actually remember the concepts you learned in class and help apply it to what you were doing. So, *I think that's what it's designed for*, but I was always doing it based on the due date." [*author's emphasis*]
>
> – Student 5, Round 2
>
> I think I definitely... I can do online classes, but I definitely prefer doing them in person. I think just having a daily schedule is definitely helpful for that… I think I really need to set a schedule for myself. I work better on a schedule, at least a little bit of a schedule.
>
> … for the econ class I'm taking right now for the Maymester, I'm trying to watch one chapter worth of – it'll be more like I just have to finish one chapter's worth of lectures a day, not like, 'this time of day I need to finish it'. I don't know if that'll make it better for doing it or not, but that's at least the way I'm approaching it right now.
>
> – Student 5, Round 4

Many students also reported a new appreciation for, and understanding of, the role of physical devices and spaces in learning after moving home due to COVID-19. Often, this resulted from their constant use of personal computers: students engaged with a single device to access the bulk of their resources for academics, entertainment, and social engagement. Conflating all these purposes in the context of a single space, like their computer or their bedroom, could wreak havoc on students' ability to focus on their academic work.

> "It's kind of strange having to transition. It's not as much of a workspace anymore now that it's where I watch videos and stuff, and watch movies, and then play games with my friends. So it's hard to separate that from doing work, which was something I could definitely... If I was like at [the library] for instance at Purdue, I didn't really do any of that stuff because I would just study or do my homework. That was definitely the toughest part, I think, is just not having that separation."
>
> – Student 5, Round 4

"…when you're taking an exam, that's usually only an 'exam place', if that makes sense. I don't know, my brain just switches over to exam mode. Whereas now – oh, just doing some homework. Okay, hanging out. I'll throw YouTube on the split screen and it's like NO! No, you can't do that. Can't do that, you're taking exams.

…now, it's like, okay, I'm sitting at my desk, it's time for an exam. I'm sitting at my desk, it's time for homework. I'm sitting at my desk, it's time for a lecture. It's hard to differentiate the space, if that makes sense."

– Student 4, Round 3

Sometimes, students' adaptive behaviors were motivated by circumstances which prevented them from engaging with their preferred learning resources. These processes of adaptation could also lead to transformative experiences as students reflected on the changes they were forced to make. For example, before the switch to online learning many students reported that they were primarily individual learners, only occasionally engaging in collaboration outside of class. After the switch however, many students acquired a newfound appreciation for the many brief, incidental interactions that they would have with their peers or instructors over the course of the day. Student 4 provides as especially clear example of this.

"I think it's hard because you don't really realize how much you talk to other people, or work with other people, or ask a passing question when you're having lunch with somebody, or little teeny interactions that are pretty unnoticeable. But when you don't have those interactions, you realize, 'Oh, I wish I could ask my friend, X, about this.' Like, if you're having lunch and you're talking about, for example, the dynamics homework, like, 'Yo, did you get a negative answer for velocity? Did you get it so it turned around?' If they're like, 'Oh, yeah, I definitely did,' then you're like, 'Okay.' Then, when you later see you have a negative answer you're like okay, all right, this feels good. Whereas now it's, 'Did I get this right? I don't know.' You're trying to figure it out, you're going back over it. …now, it's hard to have those quick, almost passing interactions.

I don't think you can really make up for those small little interactions. I work with a couple of my friends on Dynamics and on ECE and we text about the homework. I'm, 'Oh, you know, I'm stuck here, how'd you finish this or that?' So, we work like that and try to simulate that group; basically feel like we're in a group working on it. But it's obviously – it's not the same as actually being there."

– Student 4, Round 3

Finally, I would be remiss not to mention that some of these students' transformative experiences may have been facilitated by their participation in the interview process itself. A few students reported after the end of each round that they enjoyed the interviews, and that the

interview process itself was useful for reflecting on their own study habits and routines. These positive and reflective experiences are not necessarily surprising in the context of phenomenographic interviews, but they should be kept in mind as a possible catalyst for the adaptive and transformative experiences reported throughout the interview process. Although most of my discussions with participants about the interview process itself occurred after I had stopped recording, there is one quote from the final round of interviewing that demonstrates this trend.

> "[participating in research at Purdue has] just been something I've enjoyed doing but like, this has been the [research project] that I've enjoyed the most… This is the one I look forward to the most, and I am sad it's ending."

> – Student 8, Round 4

Relating between Categories: Individualized Student Learning Experiences

In summary, Circumstantial categories describe experiences of implementation in which students are forced to adopt, or not to adopt, specific resources or innovations by circumstances which lie beyond their control. Preferential categories differ from the Circumstantial in that students are not forced to take any action. Instead, they are free to demonstrate their own agency by adopting, or not adopting, resources that fit with their own personal preferences and familiar approaches to learning. When students take a step further and go out of their way to access new, unfamiliar, and previously inaccessible resources their experiences fall under the Adaptive category. Here, students are motivated to move outside their comfort zone to account for extenuating circumstances or to engage with resources that they perceive to be as highly valuable for their learning. Finally, students who learn valuable lessons about their own learning as a result of these processes of adaptation exhibit experiences that fall into the Transformative category. Transformative experiences are typically accompanied by reflection, with the student taking time to examine their own learning in light of new and past educational experiences.

Embodying Differences in Implementation using Student Engagement

The concept of student engagement can take many forms in the context of educational innovation. In their exploration of student engagement in the university setting, Kahu & Nelson (2018) characterized student engagement in learning opportunities as being composed of three dimensions: *emotional* (students' affective perceptions and predilections), *cognitive* (students'

critical approaches to learning, including differences in surface and deep learning orientations), and *behavioral* (the habits, actions, and interactions evidenced by students). Each of these three dimensions of engagement are presented as being influenced by a variety of individual and institutional factors, each of which interface with one another to determine individual instances of student engagement and their various outcomes (Kahu & Nelson, 2018).

In this study, students reported engaging with resources in emotional, cognitive, and behavioral ways on a regular basis, with the dominant forms of engagement varying among the demonstrated categories of description. There also seemed to be stark differences in student experience when comparing between implementations that involved cognitive and *metacognitive* forms of engagement. Generally, metacognition would be considered as one aspect of the cognitive dimension of student engagement (Kahu & Nelson, 2018). However, the differences in student experience presented by the participants in this study necessitated a clear distinction between metacognitive and cognitive engagement. Table 8 below depicts how student engagement was demonstrated across the various types of implementation experiences defined through Phenomenography.

Table 8: Variations in student engagement across Phenomenographic categories of description.

Category of Description	Primary Loci of Influence	Primary Modes of Engagement
Circumstantial Non-Adoptive	Circumstantial	Emotional
Circumstantial Adoptive	Circumstantial	Emotional Behavioral
Preferential Non-Adoptive	Preferential	Emotional Cognitive
Preferential Adoptive	Preferential	Emotional Behavioral Cognitive
Adaptive	Mixed	Emotional Behavioral Cognitive
Transformative	Mixed	Emotional Behavioral Cognitive Metacognitive

Although differences in student engagement are intriguing, perhaps the key takeaway from this table is that engagement is *not enough* to capture all the nuance of students' implementation experiences. While engagement can help us differentiate between some types of implementation experiences, these differences are only one piece of a larger puzzle. These findings suggest that investigations into the implementation and use of educational innovations cannot depend solely on measurements of student engagement (or conversely student resistance), especially if *behavioral* engagement is all that's being captured through, for example, resource usage data. Limiting an analysis of implementation to the behavioral engagement exhibited by students would vastly oversimplify the scope of students' possible implementation experiences. Teasing apart the differences in students' experiences of implementation, and understanding their implications for engineering education, requires going beyond simple conceptions of resource usage or engagement. Instead, we need to thoroughly examine the unifying theme which defines this Phenomenography's hierarchical structure: the self-direction of students' own implementation experiences.

Describing Affective Differences in Implementation Experiences

It could be argued that the results of this Phenomenography should yield four categories instead of six. For example, having a clear four-step progression from Non-Adoptive to Transformative experiences would fit well with existing models of implementation. Alternatively, having a four-step hierarchy moving from Circumstantial to Transformative experiences would establish a clear relationship among categories based on students' metacognitive awareness and self-directed learning behavior. While both four-step categorical definitions might be useful, I do not believe that either would be authentic to the students' own reported experiences; or at the very least, not when presented in isolation.

This is most clear in the distinction between Circumstantial Adoptive, Circumstantial Non-Adoptive, and Preferential Non-Adoptive categories. There is an obvious difference in students' affective perceptions of Circumstantial Adoptive and Circumstantial Non-Adoptive experiences. Circumstantial Adoptive experiences were discussed with a begrudging sense of inevitability or, in the case of students who established mutual accountability with their peers, as a necessary evil of sorts. Circumstantial Non-Adoptive experiences on the other hand were universally accompanied by a sense of regret, and students' descriptions of the resources that they were

prevented from using were often framed in a positive light. Students seemed to discuss Circumstantial Non-Adoptive experiences in contrast to another, *assumed* adoptive experience that they had been prevented from pursuing. Finally, Preferential Non-Adoptive experiences were entirely different from Circumstantial Non-Adoptive experiences, in that students felt empowered to pursue learning according to their own needs and values. There is a stark difference between the positive and agentic experiences described in the Preferential Non-Adoptive category, and the negative futility of experiences in the Circumstantial Non-Adoptive category. Therefore, limiting the findings to a total of four categories of description is simply not enough to capture the full range of variation in experience evidenced by the participants in this study. Only through the combination of influencing factors (Circumstantial and Preferential) and demonstrated implementation behaviors (Non-Adoptive and Adoptive), can the categories both differentiate and encapsulate the full range of participant experience.

In contrast to the first four categories, Adaptive and Transformative experiences combine both Circumstantial and Preferential influences as key drivers of students' implementation behavior. Adaptations are necessitated and influenced by both Circumstance, and personal Preference. There is no obvious additional insight to be found (within the scope of the interviews included in this study) by trying to distinguish between adaptive experiences that are "mostly circumstantial" or "mostly preferential" in nature. The same can be said of Transformative experiences of implementation. The only difference between Transformative and Adaptive experiences is students' own metacognition and reflections on learning. However, this one difference creates a fundamental change in the students' experience of implementation, establishing an opportunity for long-term change and deep insight into the students' own educational needs.

In the final phenomenographic outcome space depicting student experiences of implementation presented in Figure 5, the categories of description become increasingly self-directed and individualized as they progress along the arrows from Circumstantial, to Transformative. The distinction between Adoptive and Non-Adoptive experiences in the earlier categories is a necessary complication as they represent fundamental differences in student experience as demonstrated in this study.

Narrative Findings

The following narratives are works of research-based fiction. Each of the four characters whose brief stories are listed here were constructed via the combination and interpretation of interview data drawn from a number of participants. These constructed narratives are intended to simultaneously clarify *and* complicate readers' understandings of students' experiences of implementation. Clarify, by demonstrating examples of different implementation experiences, and complicate, through the provision of background information, the description of significant moments of experience, and the introduction of productive ambiguity among the strict categories of description produced via phenomenography.

Within the following stories the boundaries defining where one experience of implementation might end, and where another may begin, are intentionally vague. There are no efforts to explicitly label or categorize what each character is going through. This is because each participants' experiences of implementation in *Freeform* constituted pieces of a much larger story, requiring hours of interviewing and reflection to elucidate. I hope that by presenting some of these experiences within the context of a broader narrative, I might also encourage my readers to pursue a process of reflection and growth similar to my student participants as they engage and empathize with the characters they encounter. For the sake of transparency, I have included Table 7 to communicate which participants' interviews contributed to each of the characters represented in the stories below. I developed each character through the combination of at *least* three student participants to ensure that no single character was too similar to any one participant.

Table 9: Student influences on character formation.

Character Name	Major Influences	Minor Influences	Formative Character Traits
Lucas	Student 1 Student 4 Student 12	Student 2 Student 6	Non-resident Change-of-Degree Student Socially Isolated
Kate	Student 3 Student 6 Student 11	Student 10	In-state Resident Negative Prior Experiences Independent Learner
Vergel	Student 2 Student 4 Student 13	Student 1 Student 6	Non-resident Sensitive to Disruption Physical Impairment (TBI)
Timothy	Student 5 Student 8 Student 9	Student 12	In-state Resident Externally Motivated Socially Engaged

Background: Prior to the 2020 Spring Semester

Kate: March 15ᵗʰ, 2018

"Alright, we're going to work with partners now on this assembly" the instructor said, holding up a machined metal flange at the front of the classroom

The goal of the activity was to design the most efficient assembly process: ideally, one that would require moving the product as little as possible. It wasn't anything too difficult as far as the course went, just some sketching and creative thinking. That said, manufacturing concepts were still fairly new to the various high school students in the classroom.

Kate bent down to her notebook and got to work, not bothering to watch as the rest of the class, all boys, paired off one by one. She knew the drill by now. She'd learned it back in Junior year.

A few minutes had passed before the instructor started to walk around the classroom, talking quietly to a few of the students and offering advice here and there. Kate was seated near the back, but he got to her eventually.

"You ok working alone Kate?", he said.

To be honest, the question almost wasn't worth answering. If she said no, she would be saying that she wasn't confident enough to do the problem on her own. They were already five minutes in on the assignment, and she'd been good at working on her own for as long as she could remember. Why disrupt the class now?

"Yeah, I'm good." she said, and continued with her work.

Lucas: September 4ᵗʰ, 2019

"So what brings you in today Lucas?" His advisor, who insisted on just being called "Jim", sat across from him in the advising office.

Lucas unconsciously sat up a bit straighter. "I want to switch majors," he said, with a bit more finality than he felt. "I think I need to be in Mechanical."

"This early in the Semester? You're barely two weeks into your Sophomore year." Jim said, turning away to look something up on the other side of his monitor. "Don't you want to give Aero a shot?"

If he was being honest with himself, no, Lucas didn't want to give Aero a shot. His dad's buddies worked over at JPL, and they had always told him stories about tests and experiments and stuff. He'd thought Aero was the perfect choice for him: it was half the reason he came to Purdue. The other half was, of course, to get away from home.

That all changed this summer though, with his internship.

"No I… No I don't. It's too restrictive. Like, I don't want to just be forced to go into something Aero related. I can always specialize in it later. I think I need some flexibility."

Lucas was repeating, basically word-for-word, what a senior engineer had told him on the JPL campus.

Jim didn't seem too surprised, just nodding in response. "So why didn't you apply last year to Mechanical then? Did First Year Engineering not give you a good idea of what to expect?"

Lucas could only shake his head. "Look. I already knew what engineering *IS*, I just didn't know what an aero engineer *DOES*. FYE told us about what's important for engineers to know and what they expect us to learn but like, none of it was in context." Lucas stared at the back wall, searching for the words he needed. "I got to see it during the summer and just, I dunno. Something was just like, off, you know?"

Jim looked hard at his monitor for a moment, then turned to Lucas once again. "Well, you've got the grades for it," he said, "let's see if we can't get a change-of-degree process going."

An unexpected sense of relief washed over Lucas when he heard those words.

"Awesome. Yes, let's do that."

Vergel: November 22nd, 2019

Vergel sat on the edge of his bed in the dorm, wracking his brain in quiet desperation. He was trying to remember the topic of yesterday's lecture in Thermo, but it felt like he was sifting through fog. It should be easy to bring yesterday to mind. This whole thing should be easy.

But minutes passed, and nothing was there. It was like there was a void in his head where that class should've been. They'd covered… convection maybe? Some sort of transfer?

The screen on his laptop was blank, but ten minutes before he'd been looking up his grade on the second midterm exam. It wasn't pretty. Vergel had never even *seen* an exam grade in the 30's before, much less received one himself.

His gaze wandered around the room, finally hesitating at the door to the en-suite bathroom. He was pretty sure he knew why this was happening. It was just, surprising, in a way.

He'd never had a concussion act like this before. Not after hitting his head playing futbol Sophmore year of High School, or even when he wiped out on his longboard Senior year.

Falling in the shower shouldn't be able to do this. Old people get hurt slipping in the shower, not college guys, and definitely not athletes. He hadn't even felt nauseous or anything.

Vergel put his head in his hands, mind fading to static once again.

The words, "What do I do?" sounded hollow in his own ears, muffled by the hands that hid his face.

Spring Semester Begins: January 13ᵗʰ, 2020

Vergel: January 13ᵗʰ, 2020

Vergel took a step back, looking at his work in satisfaction. He'd never lived in a room this organized before. It was honestly hard to believe that he was the one who organized it. But he was. It was all part of the master plan, actually. This semester was going to be different. It had to be, given the state of his GPA. He'd spent some time over Christmas break visiting a neurologist, learning more about concussions and what exactly might be going on in his head. They'd let the University know about his situation, but it wasn't like the Purdue could just take care of everything.

There were a few coping mechanisms that he'd learned about over the break that he would be putting to use this semester. For one, he was going to guard his sleep and go to bed early to like, maintain a proper routine and sleep schedule. For another, he'd be maintaining a workspace that was separate from where he slept and socialized. Sure, the dorms could make that difficult, but he'd do whatever he needed to.

Beyond that, he was going to be writing important things down. That, and repeating them. Anything to help his brain reinforce his short-term memory. He'd devised this whole system using post-it notes, just to help him keep stuff in order.

A notification went off on his phone, reminding him about his class in 20 minutes. Vergel went to his bookshelf and took down the lecturebook and a blue notebook, the color he decided to use for Dynamics.

He knew what needed to be done in order to get through the semester, and he'd done everything he possibly could to prepare. Now, all that was left was to make it happen.

Kate: January 29ᵗʰ, 2020

Kate stepped out of the Corec into a chilly winter morning.

10:30AM, and she was finally headed for her first class of the day. A design class, unfortunately, since that meant all the work was group work. Sure, admittedly she got along fine with everyone. She'd just prefer to work alone.

On the bright side, she'd been able to get to the gym first thing in the morning. Her schedule for the semester was the dream: taking care of all her classes right in the middle of the day left the morning open for working-out or sleeping-in, and the evening open for homework. Last semester all her classes had been scattered around, which was an absolute nightmare to get used to.

Kate hesitated for a moment on her walk to the classroom, bringing her backpack around to double check that her lunch was there. Once she started her first class, she wouldn't have any time to grab food until 4:30PM.

It was a big chunk of time. To be fair, it was kind of annoying that her courses always overlapped with the open-hours of the dynamics help room but, to be honest, she probably wouldn't use it anyway. If she couldn't figure the homework problems out on her own, it's not like it would help to have some grad student spoon feed her the answers. How could anyone learn like that?

Her phone buzzed as she neared the classroom and "T-Bell tonight?" flashed its way across the lock screen. Kate smiled. Having a boyfriend to bring her food during late night study-sessions was honestly the only help she needed.

Timothy: February 8ᵗʰ, 2020

Tim put down his pencil and stretched, feeling a bit more secure about his schoolwork. He's just finished the Dynamics assignment he had due for Monday, leaving a good chunk of his weekend free to socialize. It felt good; like he'd finally found a routine that works.

The first few weeks of the new semester were always rough. In the Fall, he'd been lucky enough to have all his courses scheduled in the late morning and early afternoon. In the Spring though, they were all over the place. He had an 8:30 and a 3:30 class on the same day. It felt like all his

daylight hours were eaten up by classes, and walking to classes, and waiting for classes. It was a grind.

For the first time since coming to college, Tim'd had to figure out how to make use of those random off-hours between his courses. He had to, just to keep up with the course work. Working ahead on the weekends had helped a lot as well. He didn't have to feel guilty about hanging out on Sundays anymore.

The clock read 6:54PM as Tim packed up. It was Saturday, which meant game-night for him and the guys in the dorm. As the stress had built up last semester his friend group had got in the habit of meeting up every Saturday, usually to play big, loud, multiplayer games like mario kart and smash bros. Tonight was no exception and, with his Monday homework well on its way to being done, Tim headed out guilt-free. The Saturday get-togethers were a big part of what inspired him to get organized in the first place. It was good to get out now and then.

Lucas: February 10th, 2020

"…and that's all for today folks. Don't forget our quiz on Wednesday."

Lucas couldn't help but stretch as he got up from his desk at the end the day's Dynamics lecture. He'd started going to a Cross-Fit gym in town recently, and his body was still complaining about the aftermath of his last workout.

As other students flowed around him on their way to the door he couldn't help but look for a familiar face or two; only to come up empty. After his change-of-degree, most of the engineering friends he had were either on a different class schedule, or were still back in Aero.

Shrugging off the isolation, Lucas grabbed his bag and headed for the door. Next stop was the Dynamics help room. He'd gotten into the habit of doing his homework there: at first, just so he could ask the TA questions on-the-fly, but he'd started to get to know a few of the regulars there. His reason for going was changing, and working alone was hard: whether at the gym or at school.

"Lucas! Have you looked at Problem 2 yet?"

Right after walking in the door Lucas was drawn over to the study group, already in full swing.

"Nah man, I didn't check it out this morning." He said as he joined them. He took out his laptop to pull up the homework problems for the day. He couldn't help but reflect that, despite a rocky start, the semester was finally starting to come together.

Kate: March 11th, 2020

Kate found herself lost in thought for the third time that evening, staring out over her half-filled suitcase and the pile of clothes on her bed, waiting to be folded and packed away.

She'd been hesitating to take the plunge and head home for while now, mostly due to her part time jobs and student loans. Yesterday, the announcement from Purdue that campus would be closing had made up her mind for her. Now all she had to do was pack and head back, at least in theory.

But something wasn't sitting right with her.

Finally giving into her anxiety, Kate took a seat on her desk chair, ignoring the pile of clothes for a moment. A few quick swipes and she'd pulled up her parents' number, ready to dial. She couldn't remember the last time she'd actually called her house's land line, but everybody should be stuck at home because of COVID, right?

The phone rang a few times, and her dad finally answered with a classic land line, "Hello?".

"Hey dad, It's Kate." Kate said, going with the flow. "I know we talked about me coming home in the next couple days, but there's something I wanted to check first."

"Yeah? Sure, what's up Kate?" Her dad said. He'd immediately started using his 'problem solving' voice.

"I just… things work different when I'm at home, right? Here I'm sleeping in, and working out early, and doing homework late… I like my schedule, and I like to do my own thing. Do you think you and mom would be ok with me, like, just keeping that going, once I get home?"

She felt like she was rambling, but she wasn't quite sure what she'd wanted to say in the first place.

"I've got a way that I work best here on campus, and I just wanted to check if it would be ok with you two if I just… keep doing that. I'm gonna be busy, especially during the day, and I'm not going to have time to do like, family lunch, or that kind of thing. Is that alright?"

There was a brief pause from the other side of the phone, but her dad was quick to respond.

"Of course." He said. "We want to support you however we can. I guess I hadn't thought about it, but both your mom and I should be home for the foreseeable future. I'm sure we should be able to take care of the household chores and such. It's not like we don't do that already. I mean, this is just all so crazy…."

He paused for a moment before moving on, "… I'll let your mom know about it, and we can work the details out once you get here, ok? I'm sure there's no problem with you doing lunch on your own. We'll make sure not to get in the way."

Kate felt a little knot of tension she hadn't known she had unravel when she heard his words. "Thanks dad." She said. "I was just packing actually. I'll get back to work."

"I'll see you soon."

Spring Break Begins, Campus Closes: March 14th, 2020

Vergel: March 25th, 2020

Vergel heard the door latch shut as he pulled it closed, cutting off the sound of his family's Zoom call going strong in the other room.

He'd only moved back in a day ago but his family already had him "checking in" with his cousins down South. He'd used the excuse of being behind on schoolwork to finally get away from the clamor.

Of course, it was *true* that he was behind on schoolwork. Moving back home had taken up more time than he'd thought.

Vergel walked across his bedroom to the makeshift desk in the corner. His chair sunk down beneath him as he reached out for the stack of post-its stashed beside his laptop. His shoulders hunched as he wrote "Trash 9:00PM TH" in big letters on the top note, then took the top post-it and stuck it to the wall behind his desk. The wall was supposed to be his "parking lot" for important notes that he couldn't forget, or at least, that was how it worked in the dorms. Now it was packed with mealtimes, events, and household chores; family-responsibilities crowding out the usual academic deadlines.

Vergel had joked with his family before about how he'd have gone insane if he'd stayed on-campus after Spring Break: stuck all alone with a big dorm all to himself… After two night at home, he wasn't so sure anymore.

Vergel swiveled his chair around and leaned back, putting his feet up on the bed. Laughter filtered in from outside the door as he glanced down at the mental-health task list he'd made for himself a lifetime ago, at the start of the semester.

"So much for keeping the working, sleeping, and social spaces separate." Vergel muttered.

He smiled at his parents' laughter, but also knew it'd make concentrating difficult. Maybe next he'd invest in some earplugs…

Kate: April 2nd, 2020

The clock on her computer read 11:00PM as Kate clicked on the thumbnail of her next lecture video. It was only the second week, but she already felt like this whole remote-learning thing was a dream come true.

After the video started, she immediately went to adjust the video playback speed to 'x1.5', accelerating the video just enough to shave off a few minutes' worth of time. Lectures were So. Much. Better. with a fast forward button. She didn't even bother with the lectures for a couple of her classes anymore. The textbook was more than enough for most of her homework problems.

After the switch to remote learning everything just felt so much *faster*. She didn't have to walk to campus or commute to work anymore. There was no need to sit through hours of lecture or to drag her way through group activities. Sure, homework was the same as it had always been, but now she got to pick specific lectures and specific readings to do, maximizing her time by fitting her learning directly to the homework.

To be honest, she had more free time than she really knew what to do with. She'd kept almost the exact same schedule that she had while on campus: sleeping in, working out, staying up late when necessary, but it almost felt like overkill now.

…And through all this she couldn't help but wonder: why weren't all classes taught like this?

Lucas: April 3rd, 2020

The chair creaked beneath him as Lucas sat down heavily at his desk. It was late on a Friday evening, two weeks after campus officially shut down.

Reaching down, he thumbed the button to power on his PC and waited for the familiar login screen to pop up. With nothing to distract him, he could only stare down at the keyboard on his desk.

Lucas fidgeted, almost nervously.

Friday nights were different since the switch to remote learning. He used to get all his schoolwork done in advance by going to the TA help room, leaving Friday nights open for hanging out with friends and the weekends open for events and studying and such. Now, there was no motivation to work ahead. 10:00PM had already come and gone, and he'd only just started on his weekly assignments. He wasn't sure that he could even get things done in time anymore.

The login prompt finally appeared, and the click-clack of keys broke the silence as he entered his credentials. Twitter popped up as Chrome opened automatically, restoring his most recent tabs. It showed the homepage for one of his friends from campus, and a quick glance confirmed that there were no new tweets since last week. Lucas clicked through to the pages of a few other friends, but updates were scarce. Everyone must have been busy since the switch.

He reached down, unlocking his phone only to be greeted by "10:22PM | 60F in Santa Clarita" on the lock screen. He had forgotten, it was after 1:00AM back in Indiana.

No use texting that late… or that early, but maybe that was for the best.

He turned back to the computer with a sigh. Clicking through to the previous day's lecture, Lucas started taking notes in the monitor's blue-white glow.

Timothy: April 9th, 2020

Tim stared down at the laptop on his desk with a critical eye. He'd learned early-on during Freshman year that he couldn't bring his laptop to lecture with him. It was too easy to get distracted with his computer open – the internet just a few clicks away. Ever since, he'd taken his notes on graph paper, sometimes going so far as to leave his laptop in his room when he left the dorm for the day.

Now, his laptop *WAS* his lecture, and he still wasn't quite sure what to do about that.

Tim decided early-on to stay in the dorms. Sure, his friends were headed home, but he didn't want to get stuck back home with his parents. Besides, the internet was spotty at the house back in Indy. Going to classes and opening Chrome were basically the same thing now. He couldn't afford to have a bad internet connection.

Sure enough, the moment his laptop powered on a distraction popped up but, thankfully, this was a welcome one. The group had still been getting together every Saturday night. It just happened over Discord now, rather than in-person. The pop-up Tim encountered was a just a Discord message; Raul was wondering if anyone wanted to hop in a call to talk about Dynamics homework before their weekly meet-up.

Rather than being distracted by this, Tim felt motivated. At least he had something to look forward to. He could still remember how freeing it was to work ahead on homework at the start of the semester. Maybe it was time to get back into that routine again.

Lucas: April 10th, 2020

Lucas had gotten into the habit of sleeping-in since campus closed, so his 9:00AM alarm was the very definition of a rude awakening. Yet, barely ten minutes later, he was sitting at the kitchen table pouring himself a groggy bowl of cereal.

Plans started running through his head once his brain finally kicked into gear, and he opened up his laptop to start writing things down while eating.

He'd gotten up at 9:00 to get an early start on homework. Another week of late starts and later nights had left him with a heap of assignments to catch up on. First, he needed take care of his portion of the design project for the week, then maybe move on to thermo and prep for his meet–

"Lucas, pass the milk?"

His train of thought was derailed by his sister, who had sat down at the table at some point in time. Lucas could only mutter a quiet, "Sure," and pass her the jug.

He reflexively checked his phone after passing, but there was nothing new. It'd become a familiar ritual actually, checking for notifications and seeing nothing new pop up. Lucas hadn't realized how much he'd depended on those hours in the help room, or the quick question-and-answer sessions he used to have with the prof after class. Now it could take anywhere between minutes and literal *days* for him to hear back on questions he'd sent to his friends. It was part of why he delayed working on assignments, actually, and part of why they took so long to complete once he'd started. Having no help just made things hard.

Lucas finished his cereal and threw a quick glance at the clock: 9:32AM. He'd finally caved and scheduled a help session with one of his course TA's for 1:00PM later in the day but, to be honest, he'd kind of been dreading it. Help sessions were scheduled for half-hour time slots, but he never felt like he had a question that would merit a full half-hour's worth of time. Sure, he could get one question answered, but "the question" he wanted to ask had changed 10 times in the past 24-hours.

The questions Lucas needed answered came up as he worked, but there was no way to get instant feedback like he did back in the tutorial room. He felt guilty about scheduling a help session: it felt like overkill, and there was no way he would email the professor for little stuff like this.

Lucas could only watch the clock tick on towards 1:00PM, heralding his half-hour appointment to answer a 2-minute question. Sure, he'd probably have new questions as soon as the help-session ended, but this was the best he could do for now.

Kate: April 27th, 2020

It was midterm week. Two down, two to go, and Kate was finally closing out of a lecture on Thermodynamics, just after 1:00AM.

The new approach to exams, where all the tests were open-note and all the questions were more concept oriented, had been kind of a rude awakening. After the first two, Kate had started revisiting the lectures in order to make sure she had all the concepts down. She still felt pretty comfortable with the online stuff, relatively speaking, but she'd definitely be changing her approach to studying for the next few exams, and for the finals as well.

Her family had been asleep for hours, and while that was nothing new, it felt a bit more lonely today. Despite the good grades, it was hard to say that she was really happy with the way that things had gone. Remote learning had felt perfect when it first started up, but she didn't feel as thrilled about it anymore. Not like she did back then.

This was the time of night when she'd be having late takeout with her boyfriend. He always swore that brain food was essential for exam prep. But it'd been a month since she she'd last seen him: since she'd seen anyone really, besides her family.

The atmosphere at home was great, but to be honest, family time was getting kinda old. She never thought she'd say it, but she hoped that lockdown wouldn't last much longer.

Lucas: April 29th, 2020

Lucas laughed as he continued scrolling, using his homework progress as an excuse to check in on social media.

It was 10:00PM once again in Santa Clarita, but the atmosphere in Lucas' room had changed over the past few weeks. He'd never thought of himself as being a particularly extraverted person, but as time went by in quarantine, he'd started to see his opportunities for social interaction in a new light.

Like, who would have thought he'd spend so much time on *Facebook* of all things.

Lucas was thumbing through to the Facebook group set up by his Cross-fit gym back near campus. The gym had been super proactive about maintaining what they call a "sense of community" during the COVID-19 craziness. They'd been helping gym members set fitness goals, find mutual-accountability partners, and wrote posts at all times of day on all sorts of topics.

Lucas had never really posted much himself, but the simple feeling of having a community that was open and available had been – calming. Or like, almost stabilizing.

After catching up on recent posts, Lucas closed Facebook and locked his phone. He didn't even bother checking his texts nowadays. Instead, he turned back to his computer and opened up his next recorded lecture.

It'd taken weeks, but Lucas finally had this sense that: yeah, he could do this. It sucked, and learning took forever, but he could definitely make it work.

Timothy: April 30th, 2020

There'd been two kinds of days in Tim's life during lockdown: hectic days full of schoolwork, and lazy days spent mostly in bed. It'd been weeks of the same, with no real day-to-day routine.

Tim never did get back into his old habit of working ahead and, honestly, he felt a bit guilty about it. Classes had made his weekly schedule so easy to figure out back when he was still on campus. After all, the only reason he'd gone to bed early and got up early was for his 8:30AM class. The only reason he got homework done in the morning was because he'd had a three-hour gap between Dynamics and Math. He'd told himself a few times over the past month that he'd start going to bed earlier, being productive earlier… but without any outside responsibilities to keep him accountable, it just never really happened.

Now exams were coming up, which was just weird to wrap his head around. How did time go so fast?

The only saving grace had been his Dynamics professor. A couple weeks ago, the prof had started hosting 8:30AM Webex lectures on Tuesdays and Thursdays – and those lectures may have literally saved his grades. Sure, the content wasn't any different from the recorded lecture videos posted online, but having a designated time to learn a specific subject had helped him to finally get up and be productive in the mornings.

Tim had also started to notice another change: he was remembering the stuff he learned much better now that he was spacing lectures and homework out over the course of the week, rather than stuffing all his lectures and homework on one subject into a single day.

The thought had actually occurred to him: this is how he needed to study for exams too. The exams this semester were especially important, given all the COVID craziness, and they were way more concept-focused than the exams had been on-campus. Maybe by spacing out his studying, he'd actually remember more.

DISCUSSION

Implications of the Narrative Analysis

The purpose of conducting a narrative analysis in parallel with the phenomenography discussed above was to provide an accessible, empathetic, narrative context to an otherwise entirely paradigmatic perspective. Although the ability to label students' experiences of implementation using various categories is useful, it is important to maintain an awareness of the shear complexity of the students' lives in which these experiences were demonstrated. To address RQ2, I wrote a series of narratives covering the perspectives of multiple representative characters each combining themes, ideas, and experiences from multiple student participants. The point of writing so many stories is that, despite the clean lines and categories presented in the phenomenography, the student experience is *messy*. The participants' experiences were complicated in ways that could never be known to their instructors, or at least, not without hours of private discussion to foster communication between students and faculty. While the phenomenography is a very useful tool, it is not a perfect summation of student experiences. Where I hope the phenomenography guides faculty to think from a new, student-oriented perspective, I hope in turn that the narrative analysis encourages faculty to reflect and engage directly with the unique perspectives and experiences of their own student learners.

As the phenomenography examined students' experiences of implementation involving specific resources and innovations, it is easy to forget that these individual experiences could occur in concert with a variety of other, simultaneously occurring implementation experiences. For example, a student might be forced to give up a certain learning resource due to circumstance and, in response, they might adapt their study habits to accommodate a previously unused learning resource that remains at their disposal. Such concurrent experiences were more common to some categories of description than others. For instance, students' descriptions of Preferential Non-Adoptive and Preferential Adoptive experiences often went hand-in-hand: one resource was typically selected instead of another due to personal preference. Preferential Adoptive and Adaptive experiences could also be brought up in response to Circumstantial Non-Adoptive experiences, highlighting the complexity of students' responses to unwanted outside influence. The intricate ways in which these experiences of implementation can interact with one another are

not evidenced in the results of the phenomenography alone, but they merit our attention when applying these findings to future research or implementation efforts.

Contextualizing the Phenomenography

The earliest date listed in the narrative analysis above is March 15th, 2018; scheduled to take place during the final semester of the character's (Kate's) senior year of high school. This choice was deliberate, as many students referenced their educational backgrounds and past learning experiences when discussing their current study habits and conceptions of learning. Three participants brought up their family histories as a strong source of motivation to succeed in engineering school: two who had parents and siblings with advanced engineering degrees, and one whose parent was a first-generation college student who had pulled his family out of poverty. These students were highly motivated to succeed, but also had well-developed conceptions of their own preferred approaches to learning. This means that despite their strong internal motivations, they still chose *not* to adopt a number of innovative resources that did not fit well with their current conceptions of learning. As we would expect, these students' motivation served to drive self-directed learning behavior (Van Laer & Elen, 2020) but somewhat surprisingly, did not lead to greater student engagement with blended learning innovations. Three other students discussed negative educational experiences that they had encountered during grade school, influencing them to become more independent and solitary learners as a means of coping with adversity: one was severely bullied, one was repeatedly ostracized by their instructors, and one had been a frequent victim of discrimination. Given the importance of students' prior experience as a variable in the study of blended learning engagement, it seems important to highlight the shear breadth and depth of the "prior experiences" that students mentioned in context with their current implementation experiences. Student 6 and Student 4 brought up memories from as early as elementary school to explain or justify their present learning behaviors. Mentioning high-school experiences in the context of the narrative analysis is not only pertinent, but is a vast oversimplification of the actual interview content.

With regard to students' prior experience in blended learning specifically, students' prior experiences blurred the line between Preferential Adoptive and Adaptive implementation experiences. We see this in the story of Timothy, whose friends were already familiar with digital communication, and the story of Kate, who took to her remote-learning resources like a fish to

water. One of the key ways to differentiate between Preferential Adoptive and Adaptive experiences of implementation appears to be simply: adaptation is difficult. Even if students want to be able to adapt to changing needs and contexts, it is not always something that they can do without some manner of scaffolding, guidance, or prior experience to ease their transition. This echoes the findings of prior research in self-directed learning and in blended learning, which emphasize scaffolding and orientation to encourage student agency and engagement (Van Laer & Elen, 2020; Taylor & Newell, 2013). Timothy had a group of friends that were used to communicating online, and their weekly meetups easily translated into opportunities for virtual collaboration. Lucas on the other hand, depended on a study group that was tied to a specific physical location and only met at certain times of day. Lucas had no precedent for online collaboration and no guidance for continuing it online, so after the switch to remote learning their study group quickly fell apart. Returning to the data, we can see an example of this in action from the experience of Student 9.

> "Well actually, before we switched to the remote learning sometimes I just like: either I visit their place or they come to my house to work […] But sometimes just, like to save time we also do it online. It doesn't [sic] really change much before and after the remote learning thing.

> … there are like, tons of ways that you can talk with people, either by phone, either like through internet, and you can send photos to each other. So, it wasn't really a difficult thing to do."

> – Student 9, Round 4

In this case, Student 9 and his friend were not forced to go through an experience of adaptation at all. They were able to continue to employ their preferred learning strategies even after the switch to remote learning. While prior experience did not allow students to automatically use resources fluently (as is suggested in literature, see: Schwenger, 2016), these experiences do seem to give students a concept of how those resources can fit into their previously established routines and study habits, mitigating the effects of major disruptions or changes to their learning environment, and easing any adaptations that must take place.

This example highlights yet another point, that implementation experiences involving collaborative learning resources can be especially difficult to navigate (as has been noted in prior research, see: Grund, Grote, & Gerber, 2004; Stites et al., 2020). In this study, this was primarily evidenced due to the fact that the availability of such resources depended, in part, of the decisions

of each students' potential peer collaborators. In the story of Lucas, we see him being forced into a Circumstantial Non-Adoptive experience on account of his peers' failure to respond to his text messages. Alternatively, if his peers were inclined or motivated to respond more promptly, they could have all adapted their collaborative study habits to better fit their new remote learning context. Student 8 discussed how her Dynamics instructor was the only professor (within the scope of her experience) who re-introduced their students to pre-existing opportunities for digital collaboration after the switch to remote learning. She tied this to the increased activity she saw on the discussion forums after the switch, which had in turn made the discussion forums into a useful resource. This echoes contemporary literature on blended learning which has been emphasizing the importance of instructor's facilitative actions in encouraging students' engagement in online collaboration (Martin, Wang, & Sadaf, 2020; Epp, Phirangee, & Hewitt, 2017).

> "The only instance of an instructor facilitating that would be in Dynamics, actually, and that's just really the course blog thing, how they're like, 'Oh, well, now we don't have office hours, so if you have questions, just post it on here.' And I think people are using that a lot. And it's helpful for me because, more often than not, people have already asked the questions that I have… Dynamics is the only specific (example of), 'Here's where I would like you guys to collaborate.'"

– Student 8, Round 3

The Adaptive and Transformative experiences of implementation observed in this analysis tended to arise in context with some sort of catalyst. This could include a change in learning environment, as we saw during the switch to remote learning. More often however, this appeared to be motived by some manner of critical incident which effected students in profoundly positive or negative ways. This may not be surprising, as critical incidents have long been studied, or even utilized, in the role of fostering transformative educational experiences (Christie et al., 2015; Tripp, 1993). However, while literature can help instructors to create critical incidents for purposes such as identity formation or professional development (Tripp, 1993), many of the critical incidents communicated by the participants in this study were both spontaneous, and profoundly negative. Seven students reported negative critical incidents that influenced their study habits during the time our interviews including chronic physical injuries, deaths of loved ones, and uncharacteristically poor academic performance. A small number of students also discussed profoundly positive critical incidents, mostly tied to interactions they had with practicing professional engineers. Lucas' encounter with a professional engineer during his internship, and

Vergel's accidental concussion, are representative of positive and negative critical incidents, respectively. Such incidents would likely be transparent to most engineering instructors, despite the profound impact they had on these students' educational experiences.

Many students who made lasting changes to their own study habits did so in response to negative critical incidents, which likewise implies the possibility that students who exhibit Transformative experiences of implementation could demonstrate lower academic performance, and poorer affective perceptions of their courses, than their peers. Just because a given implementation experience is more self-directed and more complex does not imply that the experience will translate into an immediate, positive effect on students' learning outcomes. Students who planned out changes in advance of the new semester did so due to poor grades they had received in the past, and students who learned a new appreciation for scheduling, repetition, and collaborative learning experiences did so due to the negative impact that COVID-19 had on their ability to maintain their previous study habits. While these Transformative experiences may lead to positive outcomes in the long-term, they were still catalyzed by a negative incident. If educators wish to maximize the potential benefits of Adaptive and Transformative implementation experiences, it may be worthwhile to explore how to facilitate such experiences without the need for negative incidents to catalyze students' processes of reflection and change. Perhaps simply facilitating reflective discussions, like the ones which occurred as part of this interview process, would be enough to encourage Transformative self-directed implementation experiences in students' blended learning activity (Van Laer & Elen, 2020).

I would also like to note that there is likely a difference between the level of personal agency which students perceived themselves to have, and the actual agency that those students had the potential to exercise. This goes beyond individual differences in self-efficacy and students' perceptions of control. Rather, this highlights students' abilities to *recognize* opportunities for positive change. Many students' Circumstantial Non-Adoptive implementation experiences could have been turned into Adaptive experiences if those students had been sufficiently motivated and subsequently empowered to do so. However, students must be *aware* of such opportunities in order to take advantage of them.

This once again speaks to the notion that Adaptive implementation experiences are not easy: they require energy, motivation, metacognitive awareness, and forethought to be pursued. In addition, they can not only be encouraged by outside influences, they can also be suppressed by

outside influences. It is worth noting that a perceived denial of agency can come from sources other than instructors. Peers, family members, curricular and institutional requirements, and even incidental influences (such as physical injuries) can cause students to feel a loss of perceived agency, forcing them into more circumstantially driven implementation experiences.

Implications of the Phenomenography

The phenomenography conducted to address RQ1 resulted in a six-part hierarchical framework with categories distinguishing between four levels of behavioral engagement in the implementation process (Non-Adoptive, Adoptive, Adaptive, and Transformative) and two loci of influence that impact the student experience of implementation (Circumstantial and Preferential). The hierarchical framework communicates that: as Preferential influences begin to take precedence over Circumstantial influences, and as students engage in increasingly complex implementation behaviors, students' experiences of implementation become increasingly self-directed and individualized.

These findings are significant for the field of EER for a number of reasons. By demonstrating that students can go through their own individually distinct processes of implementation, this study advocates for the treatment of students as individual implementors and agents of change, even outside the context of strictly participatory change processes. When faculty implement new educational innovations and resources in their classroom, they should not expect to gain a wholistic perspective on the effects of those innovations by simply measuring students' perceptions and academic performance. We know from prior research in the *Freeform* environment that students can have very positive perceptions of resources without ever having used them (Evenhouse et al., 2020). The stories of negative critical incidents communicated by participants in this study (see also: Evenhouse, 2020) likewise demonstrated that students can have deeply impactful, transformative experiences of implementation but still receive poor grades. In addition, students can choose not to adopt innovations introduced by instructors for entirely justifiable reasons (as literature on self-directed learning would lead us to expect, see: Litzinger, Wise, & Lee, 2005; Van Laer & Elen, 2020), implying that faculty efforts to unilaterally increase student engagement with educational innovations could sometimes do more harm than good.

Distinguishing Between "Circumstantial" and "Environmental" Influences

One of the most important distinctions between the findings of this study and previous implementation research lies in the use of "Circumstantial" as a descriptor of variables, rather than the word "Environmental". This simple change in terminology is an essential representation of how the student experience of implementation differs from previous discussions of implementation in organizational and educational change literature. Many models of implementation (as I discuss in my literature review) distinguish between two sets of factors that influence the implementation process: Individual factors (such as the user's needs and values), and Environmental factors (such as institutional culture and capability). However, the work presented here demonstrates that this terminology is not entirely appropriate when discussing students' own experiences of their implementation processes. Whereas models of implementation traditionally portray Environmental factors as a part of the overall context encompassing (and thus influencing) all implementors simultaneously, students discuss some key influences on their study behavior as being *both* external in origin *and* individually distinct.

The theoretical model from the earlier literature review, which was constructed based on research that was written to inform the actions and behaviors of faculty, and the hierarchical framework presented in this study, which was developed based on the reported experiences of students themselves, are both arguably valid. Yet, their differences highlight the importance of including student voices in EER discussions of educational innovation. For example, if a student suffered from an accident resulting in serious injury at some point during the semester, the student would perceive this injury to be an outside influence on their learning experience: an unfortunate circumstance that has inhibited their ability to engage in certain learning behaviors. Whereas an "Individual vs Environmental" duality would label personal injuries as an "Individual" factor, a "Circumstantial vs Preferential" duality allows such factors to be labeled as "Circumstantial" in nature, highlighting that such accidents are perceived to lie beyond the students' ability to control. Accidents, sickness, physical injury, the death of a loved one, even scheduling conflicts; each of these examples are frequently perceived as lying beyond the student's ability to control, yet result in a distinctly individual impact on the experience of implementation.

This is an important distinction for faculty to keep in mind. Students each come to class with not only their own preferences, but also their own unique circumstances. Students may be forced into, or prevented from, adopting certain innovations, behaviors, or technologies due to

circumstances that are both uniquely individual in nature, and beyond the students' immediate capacity to change. This idea might be best approached by using the Locus of Control as an analogue. Similar to Rotter's (1966; Wolfe, 1972) concept of the internal and external Locus of Control, Circumstantial and Preferential experiences of implementation are distinguished by students' perceptions that their implementation behavior is primarily directed and determined by external (uncontrollable) or internal (controllable) factors. Going further, Adaptive and Transformative experiences are frequently characterized by students taking control and making (Preferential) changes to their learning behaviors, often in response to the influence of uncontrollable external (Circumstantial) factors.

Following this, we can see that students' implementation experiences are not only shaped by Preferential and Circumstantial influences, but also by students' own perceptions of those influences and which, if any, they can *control*. For example, the distinction between Circumstantial Non-Adoptive and Preferential Non-Adoptive experiences can be summed up as the difference between students exerting control over their own study habits, and students having their control taken away. The difficulty in this interpretation lies in the fact that students' own perceptions of what they *can* and *cannot* control differs wildly among individuals. Circumstances which result in Non-Adoption for one student, could lead another student into an Adaptive experience as they respond creatively to the challenge put before them.

The Possible Implications of Mindset in Student-side Implementation

In their book *Immunity to Change*, Kegan and Lahey (2009) explore the psychology behind why some people are better able to change in response to challenges than others. I use the word psychology because, as Kegan and Lahey argue, the difference likely hinges on each person's *mentality*. The authors describe three levels of mental complexity which define how people are able to recognize, understand, and respond to the need for change. The *socialized* mind takes queues from the community around it, leading people to act in a way that pleases others and aligns with the status-quo. The *self-authoring* mind is able to step back and examine those environmental pressures and assumptions, formulating an individualized response to adversity that is informed by its circumstances, but not dictated by them. Finally, the *self-transforming* mind takes time to not only examine its surroundings, but to also examine itself, laying bare emotions and biases to consider not only its own needs and prior decisions, but to also see brand new opportunities for

growth as a result of adversity. Research has demonstrated that each subsequent level of mental complexity allows business leaders to better respond to challenges, perceive and assess opportunities, and effect change within both themselves and the organization around them. In exchange, each subsequent level of mental complexity requires more energy, greater commitment, and more extensive self-reflection (Kegan & Lahey, 2009).

"Immunity to Change" is described as a condition in which people may *want* to change in response to challenges and changes around them, but are rendered unable to do so due to lack of personal comprehension and capability (Kegan & Lahey, 2009). In short, lower mental complexity can prevent people from effecting change, even when they are motivated to take action to do so, due to a lack of personal awareness and individual self-efficacy. In describing people who are able to consistently adapt to new situations, upend expectations, and rise to the challenge of personal change, Kegan and Lahey highlight how important it is to keep an open mind, practice self-reflection, and to carefully examine the real-world consequences of your choices and actions. Through these transformative habits people effect change by altering, "…both their mindset, *and* their behavior; rather than changing mindset *or* behavior, and hoping the other will eventually follow." (Kegan & Lahey, 2009; pg. 224)

Although further research would be required to better translate mental complexity from the context of business management to the context of education, Kegan and Lahey's (2009) work may be useful in understanding and fostering different student implementation experiences. By encouraging reflection and providing useful feedback to help students examine on their own study habits, instructors could push students to respond to adverse circumstances in thoughtful or creative ways. This could lead to more Adaptive and Transformative experiences of implementation as students try out new approaches to studying and discover better ways to learn. On the other hand, instituting policies that force students into specific behaviors could foster a lower level of mental complexity, *compounding* their potentially negative effects: not only would students be prevented from responding to adversity in creative ways due to a lack of opportunity and agency, but restrictions on studying would also inhibit their individual *capability* to respond to academic adversity by enabling a socialized mentality, rather than a self-transforming one. Just as business leaders have the potential to transform their organizations and unlock their coworker's ability to change, instructors may likewise have both the capacity, and opportunity, to unlock the ability to change in their students.

Now, while greater mental complexity may translate into more effective business leaders, there's no guarantee that such complexity would directly translate into better learning outcomes for undergraduate students. After all, some students may consider their study habits to be more effective when they *learn more* or *learn better*, while others may think that effectiveness means *better grades*, or even *the same grades in less time.* Effectiveness can be rather nebulous when students demonstrate so many different priorities through their study behavior.

To help us understand how students respond to academic challenges, we can turn to literature on Help-Seeking Behaviors (HSBs). HSBs describe the ways in which students seek out help when they struggle with learning and may be applied to interactions with both human (Williams & Takaku, 2011) and non-human (Newman, 2008) sources of information. Much of the discussion of help-seeking revolves around the difference between *expedient* and *adaptive* HSBs (Newman, 2002), wherein expedient HSBs are characterized by students seeking rapid answers to straightforward questions, and adaptive HSBs are characterized by students seeking a more complete understanding of the problem, its context, and its possible solutions in order to draw their own, informed conclusions (Williams & Takaku, 2011). Students demonstrating adaptive behaviors seek out new resources and alternative interpretations, expanding their knowledge base and enhancing their understanding. Expedient behaviors search for a simple and direct solution to the problem, often with the goal of earning a targeted grade with minimal effort.

In considering these two categories of HSBs, we once again encounter the importance of *mindset* in students' study behaviors. Adaptive HSBs have previously been connected with intrinsic goal-orientation (Chyung, Moll, & Berg, 2010; Karabenick, 2004). An intrinsic goal-orientation indicates that students are acting on their own internal motivations and goals, while an extrinsic goal-orientation focuses on external motivators such as grades or social pressures; a distinction which parallels the differences between Kegan & Lahey's (2009) socialized and self-authoring minds. Adaptive HSBs have been connected with greater self-efficacy among students, highlighting the role of students' own confidence and agency (Williams & Takaku, 2011). They have also been connected with better grades: Karabenick (2003) found that students who demonstrate adaptive HSBs tend to outperform their more expedient peers on academic assessments. While the potential benefits of adaptive help-seeking have no direct application to the results of this study, they do provide a possible line of future inquiry. Mental complexity has yet to be thoroughly translated into the context of undergraduate education. Exploring its

implications in the context of HSBs could help to ground such research in pre-existing literature and shed light on the possible drawbacks and benefits of students' approaches to implementation.

Making and Remaking a Model of Implementation

While the definition of implementation used in this dissertation encompasses a three-stage process of adoption, adaptation, and integration, the Phenomenography identified four types implementation engagement behavior. First, it is important to note that students could choose, or otherwise be forced, to not adopt the innovations and resources they encountered. Non-Adoptive implementation experiences were an essential and valid part of students' discussions of their overall learning experience, and thus should not be overlooked in future discussions of educational innovation and implementation in EER. Second, whereas *integration* follows adaptation in implementation theory, *transformative* experiences follow adaptive experiences in the hierarchy presented here. Although the two ideas are similar (in that they similarly result in lasting change), it is necessary to distinguish integration from transformation due to the nature of the students' educational experience. While each course in which students enroll may have a distinct set of learning resources associated with it, students tend to take multiple classes each semester, and enroll in multiple semesters over the course of their degree program. The key difference between our previous understanding of *integration* and students' *transformative* experiences of implementation is that the lessons learned through transformative experiences have the potential to alter students' learning behavior related to other resources, in other classes, and in future semesters. Rather than simply integrating a resource within the context of single course, transformative experiences teach lessons that can be incorporated into students' ongoing learning behaviors.

All this implies that by using the findings of this Phenomenography, there is an opportunity to create an initial model of student implementation experiences that is distinct from those discussed in the earlier literature review. Figure 6 below takes the hierarchical results of the earlier Phenomenography and arrays the categories of description in a progression from left to right. As students sequentially become aware of innovations, adopt them, adapt them, and integrate them, they gain access to a wider range of different implementation experiences. Circumstantial and Preferential influences are indicated at the top and bottom of the image spanning the full range of possible implementation experiences. The various experiences are represented in the middle

section of the model and are tied to the stages of the theoretical implementation process to which they correspond, proceeding from "Awareness of Innovation" to "Integration of Implementation" as the reader proceeds from left to right. As discussed earlier, this progression is heavily dependent on the students' ability to exercise their own agency while studying, and is influenced by the students' personal circumstances and learning preferences.
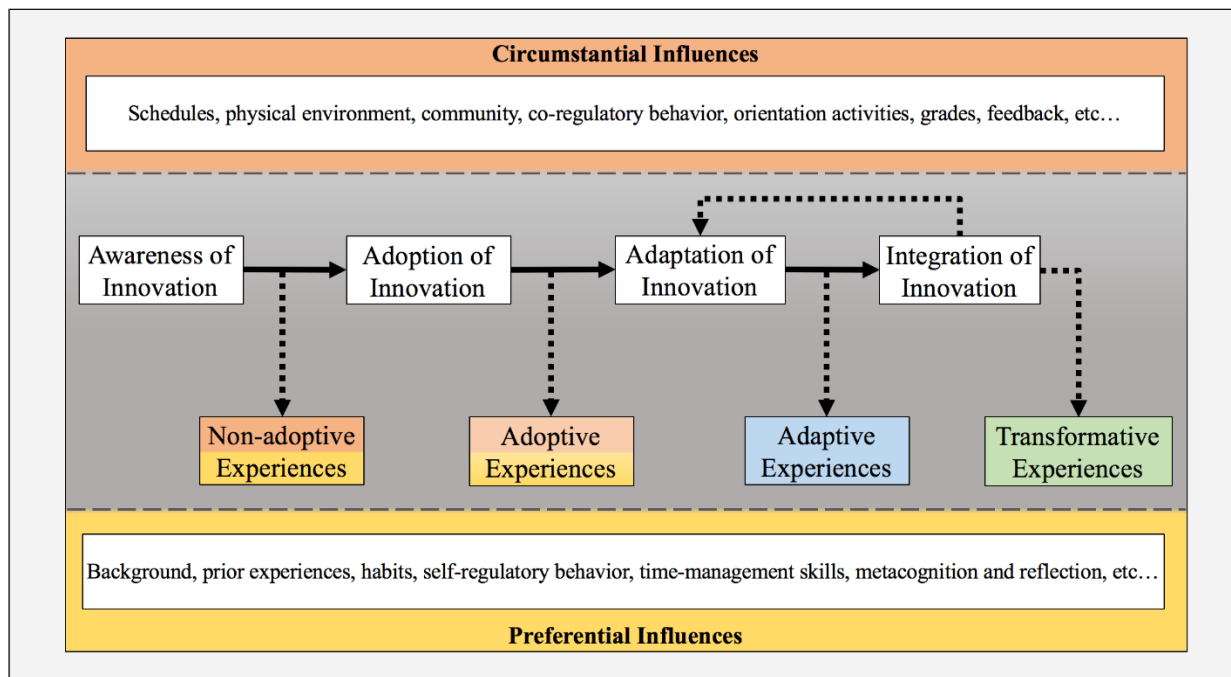

Figure 6: Student experiences of implementation as they relate to the implementation process.

This student-centered model depicting the experience of implementation can then be used to create an instructor-facing model to better inform the implementation efforts of faculty. While less authentic to the actual experiences of the students related in this study, this makes the findings of the phenomenography more directly accessible and applicable to faculty who wish to facilitate students' implementation experiences. In Figure 7 below, the progression of implementation experiences from left to right has been maintained, but the factors influencing those experiences are now labeled as "Environmental" and "Individual" to align with the instructor perspective taken in prior literature. Both groups of influencing factors also have a structure imposed on them. For example, "Communication and Orientation" are outside influences that help students to become aware of innovations so that they can be adopted, and therefore they appear at the far left of the "Environmental Factors" section. Likewise, "Metacognition and Reflection" are personal

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influences that help students to gain new insight into the learning process as part of a transformative learning experience, and therefore appear on the far right of the "Individual Factors" section. Some factors (such as Climate, Culture, and Capability) exert a strong influence on all experiences of implementation, and are therefore spread across the full length of the model from left to right. The dotted lines and arrows along the outside of the model indicate that individuals and their environments are not mutually exclusive: students can influence their learning environment, and environments can likewise influence their students.
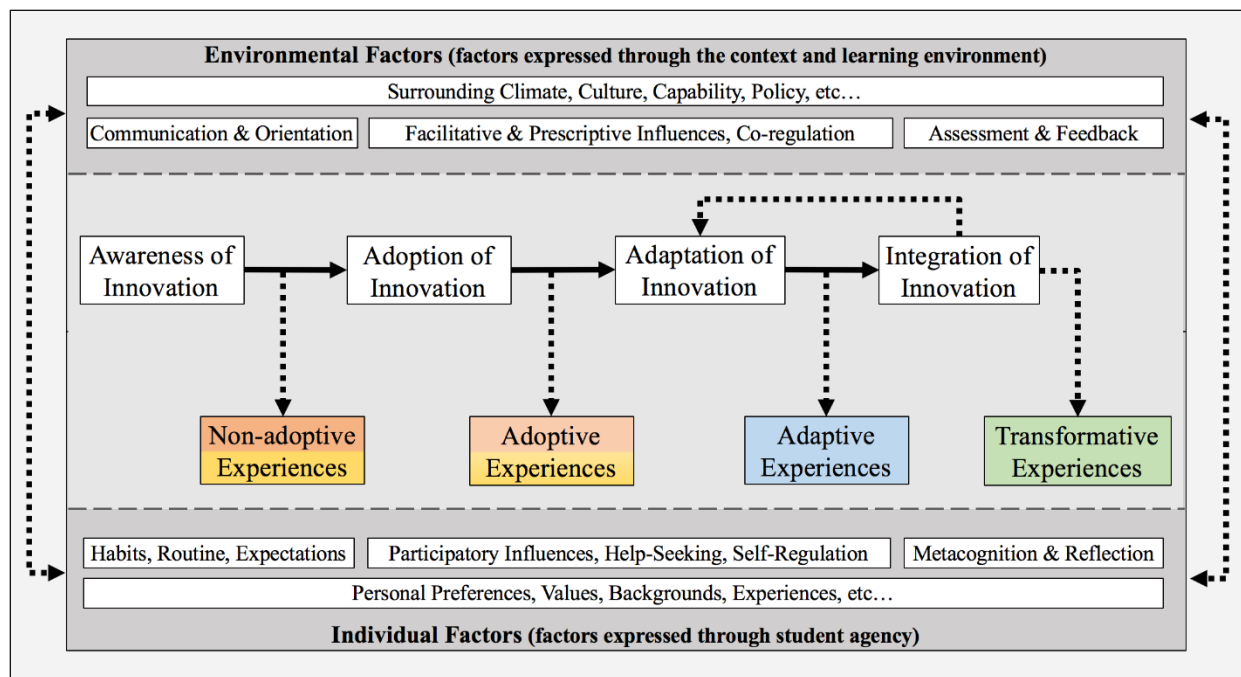
Figure 7: A faculty-focused model of implementation, relating students' experiences of implementation to the implementation process.

Where Figure 6 could be described as a model of student experience from the student perspective, Figure 7 could be described as a model of student experience from the faculty or researcher perspective.

Across both models, I hope that researchers are reminded that implementation in the classroom is not a straightforward process. Rather, it is something which students experience on an individual basis: facilitated by the actions of instructors, but not dictated by them. In fact, the reflective and individual nature of student's learning experiences in this dissertation echo the role of students depicted in some prior literature. Koenen, Dochy, & Berghmans' (2015) for example,

discussed the role of faculty as facilitators (rather than just lecturers) in the experience of student learners as part of their phenomenography on the implementation of competence-based education. Given the findings of the earlier literature review on active, blended, and collaborative learning, there may be a wide variety of innovative approaches to education in which faculty should be encouraged to play the role of facilitator, allowing students to make their own self-regulated and metacognitive learning decisions in the presence of new resources and learning opportunities. The findings of this phenomenography disambiguate what students might experience in such facilitative learning environments, potentially informing instructional practices in a wide variety of innovative settings.

Limitations and Future Work

By combining the methods of phenomenography and narrative analysis, I designed this study to produce results that could applicable to the instructional practices or research interests of a variety of educators. However, there are some limitations that should be kept in mind when applying the findings of the phenomenography or drawing inspiration from the constructed narratives to inform future decisions regarding instruction or research. There are also a number of areas that suggest future lines of inquiry based on this study; whether to address the limitations of this work, or to expand further on its findings.

Functional Limitations

Due to the effects of COVID-19 and the closing of the PUWL campus, this work was not limited to a study of blended learning as was originally intended. Rather, this work combined interviews from both blended and fully-online learning environments. While blended learning does include many online elements, the switch to remote learning still represented a fundamental change in the students' learning context. Though the data collected before and after the switch appeared to be complementary, I was not as familiar with online learning as I had been with blended learning. There is the chance that I missed key aspects of students' online learning experiences simply due to a lack of preparation. In future work, I will need to intentionally examine how the findings of this study apply to purely blended or purely remote learning contexts.

The drop in participation, also due to COVID-19, presents this study with more limitations than simply a lack of data. Polkinghorne's (1995) diachronic organizational approach to narrative analysis requires that the researcher examine how experiences develop over time, and that they seek out storylines across disparate experiences. Unfortunately, due to the 50% drop out rate among my participants I lost the opportunity to examine the completed stories of half of my participants. While narrative analysis has no strict requirements regarding the size of its participant population, this drop in participation is still significant. It implies that the narratives constructed for this study become decreasingly representative of my sample of students as they proceed through time, as I only had eight students to draw from after the switch to remote learning. In short, readers should take extra care in reading and interpreting the portions of the narratives which occur after the advent of COVID-19.

This truncation of the data collection process also held implications for the phenomenography. As phenomenographic analysis focuses on the identification of individual representative experiences, the loss of eight storylines was less of a blow as compared to the narrative analysis process. However, each of the interviews in my four rounds of interviewing were designed to build upon and clarify the results of their predecessors. Though the phenomenography suffered less from a loss of stories, it did suffer from the loss of opportunity to ask follow-up questions and member-check with students during later rounds of interviewing. This in turn weakened the definitions of my categories of description and prevented me from further exploring some important experiences of implementation that were reported early in the interview process.

Returning to the narrative analysis, one limitation to my work is simply my own lack of experience as an author of narrative works. Writing stories is an artistic skill-set (Barone & Eisner, 1997), and although I was careful in my analysis, I was limited in my ability to construct my findings in the form of a research based narrative. For example, although many of my student participants were international students, I encountered serious difficulties while attempting to write stories from the perspective of an international student. I had no confidence in my ability to depict the thoughts and experiences of such students in an authentic and empathetic manner. In the end, I did not want to risk losing the verisimilitude of my narratives by writing an international character that no one would believe. Instead, I drew extensively from the experiences of international students in the formation of my characters and plot-lines. One of my characters (Vergel) was designed to reflect the experiences of international students more heavily than the others, but none

of my characters are explicitly international. This represents a limitation to the study and its findings that comes as a direct result of my own lack of familiarity with narrative writing and the natural limitations arising from my positionality.

Limitations due to Interpretation

Phenomenography takes what is called a second-order approach to data collection and analysis, meaning that any commentary on, or descriptions of, the phenomenon of interest must come from the words of its research participants, rather than the interpretation or observations of the researcher (Trigwell, 2000; Zygmont & Naidoo, 2018). There is a very intentional engagement with, and respect of, the words of the participants in the conduct of phenomenography, allowing interviewees to report on their experiences in their own words and largely limiting the scope of any subsequent analysis to the words of the participants themselves. However, this can cause problems when participants are not familiar with the language typically used to describe, characterize, or discuss the phenomenon under investigation (Holstein & Gubrium, 2003).

Words such as adoption, adaptation, and integration, in addition to the word implementation itself, may not be a part of undergraduate students' typical vocabulary. For this reason, much of the discussion during interviews targeted students' processes of transition (both at the start of the semester, and after the spread of COVID-19), their establishment of habits and routines, and any disruptions that they were forced to navigate during the semester (of which COVID-19 and its effects were the most notable). Thus, the process of determining which of the experiences reported by the student participants could qualify as representative experiences of implementation was an act of interpretation in-and-of-itself. Although representative experiences were still analyzed in-vivo and reported in this study by quoting the words of the participants directly, the process of identifying and analyzing those experiences required more interpretation on the part of the researcher than may be typical in a phenomenographic setting. Although I repeatedly returned to review and reflect upon the data and my earlier memos throughout the analysis process, the possibility remains that some readers might interpret the experiences of the student participants differently than how they are presented here. To allow for this possibility, many of the quotations I used as representative examples above were kept lengthy, some even extending to multiple paragraphs, to allow for readers to more readily form their own interpretations of each students' experience.

In contrast to phenomenography, engaging in moderate interpretation during the analytical process is not considered a problem in the context of narrative analysis. In fact, researchers are often encouraged to interpret their data as they engage with it: constantly interpreting and reflecting on the data helps to identify possible storylines and speculate regarding their various implications. Kim (2016) quotes Polkinghorne (1995) in arguing that the act of narrative analysis itself is, in its entirety, an act of constant interpretation and re-interpretation. While Kim argues that *overinterpretation* should be avoided, it can be difficult to put a definitive boundary on what constitutes appropriate or inappropriate degrees of interpretation in narrative analysis. For the purpose of this study I very intentionally built my characters based on the self-described traits and experiences of my participants. I also constructed storylines by piecing together students' own descriptions of actual events. However, the literary forms that the narratives took were based on my own interpretation of which stories could best represent the experiences of my student population. While I tried to accurately preserve and represent the voices of my participants as much as possible, the narratives themselves are my own work.

For example, the character named Vergel suffers from a traumatic brain injury (TBI) early in his narrative, resulting in definitive changes to his study habits and behaviors. I chose to create a character suffering from a TBI in order to represent the experiences of a number of students whose learning was impacted due to circumstances that negatively effected their short-term memory, organizational skills, or even motor control. These circumstances included chronic nerve damage, medicinal side-effects, and even deaths in the family, but none of my participants actually reported suffering from a TBI of their own. To represent key aspects of my participants' stories I created a character who was suffering from a condition that I was familiar with, and could thus write about, that could capture the practical and affective aspects the participants' reported experiences. While this was effective from the standpoint of narrative construction, it does represent a limitation to the conclusions that my readers should draw from the narratives in this study. By engaging with the narratives and characters as a whole, I hope that my readers will be able to pursue a deeply human and empathetic understanding of the student experience of implementation. However, by this same token, readers should avoid making interpretations or drawing conclusions based on the minutiae of the characters' traits or the stories' narrative elements. These narratives are intended to speak to the experience of implementation; not to the experience of TBIs.

Limitations due to Framing

The results of this study revealed an internal bias I had held as a researcher during its initial planning: I set out to study students' experiences of implementation while assuming that they would have an opportunity to examine and reflect upon the resources available in the *Freeform* environment. However, the data collected has since demonstrated otherwise. To reiterate: models of implementation assume that there are methods and strategies in place to support the successful adoption, adaptation, and integration of innovations. Models of diffusion examine adoption itself in great detail due to the assumption that information about innovations must first propagate, and be examined by, potential users before adoption can be attempted. Student 5's story relating how he was unaware of the video resources in his previous course brings up a valuable point: the fact that instructors are experiencing the implementation of innovations does not imply that their students are *also* experiencing the implementation of innovations. In the same way that instructor-side implementation requires outside input and support, student-side implementation also requires outside input and support. If the instructor does not take the time to promote the usage and efficacy of the innovations they introduce the experience of students becomes one of diffusion, rather than one of targeted implementation.

I continue to use the word implementation when describing the models in this study because, for students to report an "experience" when interviewed, they must have *at least* been aware of the innovations that were available for them to implement. However, the fact that some student experiences in the Circumstantial Non-Adoptive category were impacted by a *lack of awareness* seems to imply that the exhibited implementation behaviors of some students may be better represented by a model of diffusion than the current model of implementation. In addition, framing the focus of this study in terms of implementation may have limited the scope of my data collection: diffusion (or the lack thereof) may be more prevalent in the student experience than this study can depict. The inability of my data to speak to the diffusion of innovations is an inherent limitation to the findings of this study.

In applying this limitation to my actual findings and their implications, the word "implementation" should itself imply that there are policies and practices in place that will support the students' adoption, adaptation, and integration of any innovations being introduced. Promoting students' agency does not mean leaving the learning environment unstructured, or relying on the process of diffusion in order to facilitate change in the undergraduate classroom. Rather, it means

both providing students with opportunities, and empowering students to make informed choices regarding their own learning, through preparation, communication, and ongoing support. Yes, some of the student participants' experiences could have been better framed using a model of diffusion, but I would argue that intentionally *avoiding* diffusion would be better than universally planning for it. The earlier literature review noted that students appreciate blended learning environments that are well structured in terms of both resources and content, and that allow for clear and open communication between students and instructors (Taylor & Newell, 2013; Dzuiban et al., 2018). Makitalo-Siegel, Kohnle, and Fisher (2011) likewise found that, while students in highly-structured learning environments sought out less help, they still outperformed their peers who took part in loosely-structured learning experiences. Looking beyond the learning environment itself, instructor support and rapport has been connected with not only an increased willingness among students to seek help (Kozanitis, Desbiens, & Chouinard, 2007), but also an increased incidence of adaptive HSBs (Madaio et al., 2018). Just because diffusion is present, does not mean it is desirable. With all this in mind, my goal in emphasizing student agency is *not* to promote a laissez-faire approach to undergraduate engineering education, applying innovations and allowing them to diffuse naturally. Rather, I hope that this discussion serves to spur faculty on in their course design efforts by emphasizing the role of instructors as facilitators of not only learning, but of growth, change, and implementation as well.

Investigating a 'New' Role for Faculty: Facilitators of Change

While there are many possible avenues for future work arising from this study, I would personally like to explore how to make this work more practically useful for engineering faculty. This study has cast students in a new light, allowing learners to take on the role of individual implementors in the context of educational innovations. However, this in turn implies a new role for faculty. If students are engaging in processes of implementation, then faculty are taking on an additional responsibility: to act as facilitators of their students' implementation processes and as catalysts for growth and change.

The idea of faculty acting as facilitators of students' engagement and growth is not a new concept. In the earlier literature review, the facilitative efforts of faculty came up repeatedly in context with active learning (Finelli & Borrego, 2020), blended learning (Taylor et al., 2018a), collaborative learning (Martin, Wang, & Sadaf, 2020), the use of online resources (Baehr, 2012),

and self-directed learning behavior (Adinda & Mohib, 2020). Thus, there are a number of suggestions that we can already draw from prior literature. Instructors who are aiming to facilitate the develop and success of their students' implementation experiences likely should:

- Prepare and orient students in advance of innovative instruction, empowering them to make informed decisions and scaffolding their interactions with novel resources or pedagogical approaches (Taylor et al., 2018a; Finelli & Borrego, 2020; Martin, Wang, & Sadaf, 2020).
- Generate feedback from students on a regular basis to inform adaptations to current instruction and provide appropriate guidance for students who are engaging with unfamiliar resources (Brown, 2016; Finelli & Borrego, 2020; Sher, 2009).
- Create opportunities for students to reflect on their own learning and the efficacy of their study habits to cultivate mental complexity, and encourage metacognition to foster self-regulatory behavior (Kegan & Lahey, 2009; De George-Walker & Keeffe, 2010).
- Preserve and foster students' agency by providing them with choice, and build self-directed learning opportunities into the curriculum itself (Williams & Takaku, 2011; Taylor & Newton, 2013; Dzuiban et al., 2018; Van Laer & Elen, 2020; Lindgren & Mc Daniel, 2012).
- Establish a rapport with students and keep communication open, ensuring the instructor remains available to offer guidance on implementation behavior and as a potential source of help (Kozanitis, Desbiens, & Chouinard, 2007; Madaio et al., 2018; Adinda & Mohib, 2020; Deepwell & Malik, 2008).

All this having been said, there is still much more to learn. I framed much of this paper in terms of implementation in order to inspire an alternative perspective on student engagement in blended learning, but this work could benefit from a more intentional exploration of self-directed learning practice and its connections with implementation literature. Likewise, despite the importance of self-directed learning in blended learning contexts, there is little literature discussing how to design blended learning interventions to foster and maximize self-direction learning opportunities (Van Laer & Elen, 2020). Using the results of this study as a tool could help to inform our understanding of student decision-making and self-regulation in the blended learning context. Designing for different student experiences of implementation could go on to inform broader strategies for the facilitation of self-directed learning behavior in engineering education.

CONCLUSION

In this dissertation, I set out to disambiguate the various ways in which students can experience the process of implementation in the *Freeform* environment, and to identify a way by which to authentically and empathetically communicate those experiences to readers. Phenomenography was used to examine students' experiences of implementation (RQ1), resulting in the definition of a hierarchical framework containing six categories of description: Circumstantial Non-Adoptive, Circumstantial Adoptive, Preferential Non-Adoptive, Preferential Adoptive, Adaptive, and Transformative. These categories reflect four forms of behavioral engagement in the implementation of innovations (Non-Adoptive, Adoptive, Adaptive, and Transformative) and two loci of influence which direct those behaviors (Circumstantial and Preferential). Narrative analysis was used to represent the experiences of my student participants in a manner that was intentionally empathetic, authentic, and human (RQ2). A series of brief narrative arcs centered around four fictional characters encourage readers to develop their own insights and conclusions regarding the implementation experiences of student learners, and to consider what parallels they might draw between the stories presented here and the experiences of their own student populations.

Through the combination of narrative and paradigmatic cognitive approaches (acc. Polkinghorne, 1995), this dissertation aims to not only inspire a new way of thinking about the implementation of pedagogical innovations in undergraduate Engineering Education, but to provide concrete language and representative examples to jumpstart the readers' own contemplation and conversation around the student-side of the implementation process. It also ties to literature on change strategies and student mindsets, discussing the importance of student agency in forming student-side implementation experiences and highlighting the facilitative role that faculty can take in encouraging students to innovate within the scope of their own learning. Based on the findings of this study and its accompanying literature review, instructors are encouraged to consider themselves taking on the role of "facilitator", and to allow for their students to take on the role of "implementor". Research-based recommendations related to many pedagogical innovations (including active, blended, and collaborative learning) already encourage faculty to act as facilitators of student-directed learning experiences. However, prior studies have given little insight into how to frame those learning experiences beyond the analysis of students'

perceptions, academic performance, and occasional resistance. By acknowledging the existence of these student-side implementation experiences, faculty gain the opportunity to facilitate and guide the implementation processes of students in potentially beneficial and productive ways. This study provides a framework to better understand students' experiences of implementation, and the role that instructors can take in shaping those experiences.

The models of implementation proposed at the end of the discussion section are intended to help instructors and researchers translate their new perspective on implementation into concrete actions. However, there is still much more to learn. This was a single study, conducted within the context of a single course and constrained to a single institution. Future work will be necessary to tease out the nuances of how these findings may be best translated to the implementation of other innovations in other institutional contexts. Likewise, although this phenomenography was useful for understanding and categorizing the implementation experiences of students, we still know little about the role that faculty can take in shaping, directing, and facilitating those experiences beyond what is hinted at in existing literature. However, as is discussed above, having the right *mindset* is absolutely essential to effecting change within one's self, one's peers, and one's organization. As such, it is my hope is that the literature, findings, and discussions contained here inspire, first and foremost, a change in mindset: a change in how we, as researchers and teachers, conceptualize pedagogical change in the engineering classroom. A simple switch from talking about "student resistance" to talking about "Non-Adoptive behaviors", for example, allows for experiences of non-adoption that extend beyond resistance, changing how we view the actions and roles of students and instructors in the innovative classroom. Even if there is more work to do in understanding the student-side of the implementation process, I hope that an awareness of these students' experiences can still inspire new avenues for growth and change in the EER community.

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APPENDIX A: INTERVIEW PROTOCOLS

Guiding Principles:

These interviews are a conversation about a broad, governing topic. They shouldn't proceed as a static series of questions, but as a guided interpersonal discourse. Therefore, follow-up questions should be considered after taking into account a few key concepts:

- **Intentional-Expression:** When the interviewee expresses a new term or idea, be sure to clarify what they mean by it, rather than assuming a definition. Ask for a description or an example. (Ex: "What do you mean by Learning?")
- **Free-Association:** Discussion can freely flow to topics associated with the terms which the interviewee brings up themselves. It should flow like a dialogue. However, the converse is also true. The interviewer should NOT bring in terms which the interviewee does not know or did not introduce themselves, thus forcing the conversation in a direction unassociated with what was previously being discussed.
- **Intentionality (the Subject-World Relation):** Phenomenography is concerned not with the subject, and not with the phenomenon, but with how the subject *experiences* the phenomenon. The key is to investigate the *relation* between the two, the interaction, dialogue, and meaning-making which takes place between the interview participant and world around them.

Before Every Interview:

Review the research study, researcher contact information, and the role of the participant.
1. Participation will have no effect on the participant's grade in ME274.
2. Strict measures are taken to ensure there is no potential harm to the participant. Go over the rights of the participant prior to each interview. There is no requirement for the participant to complete the interview process, nor for them to answer any of the individual questions involved. The interviews may always be stopped at any time, at no detriment to the participant. (In short: All participation is voluntary, and there are no correct answers.)
3. Participants are compensated after each individual interview.
4. Researcher contact information may be found on the consent form, which is sent electronically to the participant after signing.
5. Clearly convey the purpose behind the interview process to the interviewee: we want to better understand how students experience this course, and wish to explore how students interact with this learning environment from a wholistic, personal perspective.

Introductions: After ensuring that you have the student's email address, start the interview by recording the following:
1. State your name and the date of the interview.
2. Invite the student to state their name.

Pre-Instance/Week 1-3

Focus: Personal Description, Educational Background, Expectations, Motivations

<u>TOPIC ONE: Background and Self-Description</u>

Can you tell me about yourself?
- Here we are interested in the student's background and their way of describing themselves.
- What things come to their mind first? Set the groundwork for later comparisons between Purdue and prior experience. Open up possible routes for conversation.
- Academic and extracurricular descriptions, both from Purdue and elsewhere, especially if they can be described through a story.

EXAMPLE FOLLOW-UP QUESTIONS

How would you talk about or describe yourself?
How would you introduce yourself to the friend of a friend?
How would you describe yourself inside/outside of school?

<u>TOPIC TWO: Educational Context</u>

Can you describe what is it like for you to be a student at Purdue?
And
Can you describe some of your previous experiences in education?
- We want to know what the students first decide to communicate. What are the things which stand out as most important (or most obvious) to them.
- Comparisons to prior experience, analogies, and direct stories describing their experiences as students would be especially informative.
- We want this to be initially vague. Re-state the thematic question using different words, or re-state what the student said and ask for clarification as a means of developing the dialogue.
- Explore their perception of the Purdue "Metanarrative", and how they might perceive themselves to fit, or break, that mold.

EXAMPLE FOLLOW-UP QUESTIONS:

Are there any defining experiences that have stood out to you during your time at Purdue?
How would you describe your role at Purdue?
How would you describe a "typical student" at Purdue?
How would you describe the student body here? How would you describe your place in it?
What did you feel about education before coming to Purdue? Can you describe what it was like?
Can you compare your educational experience before and after coming to Purdue? What comes to mind?
Do you have any favorite stories or memories from you previous schooling?

What do you aim to accomplish through your study of engineering?
And
What led you to pursue this degree?

- We want to examine goals, motivations, and preconceived notions regarding their education and engineering more broadly, especially the student's internal motivations.
- See what they are prioritizing and iterate on it. What formed these opinions? Can they tell a story about how this view developed, or use a story as a tool to describe it?
- Re-state the question in terms of both long-term and short-term goals.

EXAMPLE FOLLOW-UP QUESTIONS:

What do you think it will be like to be an engineer? Can you describe what an engineer does?
What inspired you to pursue an engineering degree here?
Can you tell me a story about how you became interested in engineering/Purdue?
What expectations do you have coming into this semester?
How does taking dynamics this semester fit into your broader goals?

Week 4-6

Focus: Initial Transition, Belonging, Routine

<u>TOPIC ONE: Initial Transition</u>

How do you view your new semester?
And
Can you describe the way that Dynamics is fitting into your new routine?

- We are interested in how the students have transitioned into the new semester, and how Freeform has fit into that experience.
- The role that Dynamics plays in their daily or weekly routine speaks to how the relationship between these students, and this course, is established.

EXAMPLE FOLLOW-UP QUESTIONS

Has anything left an impression on you so far this semester? Do any stories stand out?
Can you describe a typical day for you? What do you do each week?
How do you experience Dynamics each day? Where do you interact with it? How do you interact with it?
What role do your courses play in establishing how your semester will go? What role does Dynamics play?
What influence do you have on role Dynamics will take in your life this semester?

<u>TOPIC TWO: Belonging and Comfort</u>

Can you describe how you are fitting into ME 274?
And
How does this course fit with your other experiences in the engineering community?

- Here, we are investigating the student's sense of belonging and comfort in the Freeform classroom. Every class is new at first, but we want to know their initial impressions and first takes on this course, and how they fit in it.
- Comparing this to their other experiences in engineering allows us to explore what makes Freeform different, as well as to probe their feeling of belongingness and comfortability more broadly. This will be especially important for minority populations we've previously identified.

EXAMPLE FOLLOW-UP QUESTIONS:

If they ask for clarification, ask about what they think their place is in ME274, or if they feel they belong in the class.
Do any experiences come to mind as times where you felt strongly that you did, or did not, fit with the class/community around you?
How do you feel when you engage with Dynamics, in-class or elsewhere?
How does the class play a role in the experience/learning process?

Week 9-12

Focus: Engagement with Freeform and the Learning Experience

<u>TOPIC ONE: Freeform Experience</u>

How would you describe your experience in Dynamics class thus far?
And
What stands out to you about your time in this course?

- With these questions, we are looking for salient and significant moments of experience throughout the semester. Stories that are represented of the in-process Freeform experience.
- Try to elicit reflection and meaning-making through stories, analogies, and comparisons to other courses. Especially if their relationship with Freeform can be put in context with more traditional courses. What makes Freeform different, if anything?
- Many opportunities to clarify and follow-up on previous responses to Week 3 questions on the course and class community.

EXAMPLE FOLLOW-UP QUESTIONS

How would you describe ME 274 to someone who has never taken Dynamics at Purdue?
Why does that (why do those things) stand out to you? What makes them important to you?
Do you feel as though others who have taken Dynamics would share your perspective on this?
How do you feel about Dynamics? Do you have a place in ME274?
How does the class/community play a role in your experience in Dynamics?

<u>TOPIC TWO: Freeform Engagement</u>

How do you learn and work in ME 274?
And
How do you typically learn and work as a student?

- Similar to the previous question, we are looking at what sets Freeform apart from other courses. In this case, how it relates to student's study behaviors. We are interested in what stands out to students as interesting or unique related to their work in ME 274.
- Once again stories, analogies, and comparisons will be excellent tools for collecting information.
- Explore the emotional aspects of engaging in Freeform in this way. Why do these things stand out? What makes them personally meaningful?

EXAMPLE FOLLOW-UP QUESTIONS

How do you learn best, and how do you see that fitting into your Dynamics experience? How have you been able to influence this process? How has the course influenced you?
Have you ever felt as though you had to overcome challenges, or barriers, in order to complete your coursework in engineering? How does this relate to your individual courses? To ME274?

Post-Instance/Week 15-17
Focus: Reflections on the Freeform Environment, Meaning Making, Development

<u>TOPIC ONE: Moments of Experience</u>

Can you describe your experience with ME274 this past semester?
And
Do any moments stand out, or stories come to mind, as you reflect on your time in ME 274?

- What do the students bring up first? What do they concentrate on? What parts of this class are leaving a lasting impression?
- Were these experiences individual, or collaborative?
- How did these experiences of the course relate to, and interact with, concerns from outside the class?

EXAMPLE FOLLOW-UP QUESTIONS

What did you do as a student in ME274?
What led you to study and work as you did in ME274?
Are there any moments from this past semester which stand out to you as a great example of what ME274 is, or as demonstrative of what this course is all about? If you had to sum up ME274 in one description (or one story), what would it be?
Are there any stories or moments that stood out to you as especially impactful this semester from your other courses? How do these other stories relate to your ME 274 experience?

<u>TOPIC TWO: The Role of ME274</u>

Looking back now, how do you feel about ME 274 as a course and its role in your semester?

- We want to know where, and how, Freeform may be having a broader impact on the undergraduate student experience.
- Was there anything different about the way Freeform related to these students, vs other courses?
- We want to be able to comment on how students relate to ME 274, and what aspects of that relationship shine the brightest.

EXAMPLE FOLLOW-UP QUESTIONS

How did ME 274 compare to your expectations about the course?
How did this course impact your life outside of class? What role did you play in deciding this impact?
As you walk away from ME274, what are you taking with you? What are you leaving behind?

<u>TOPIC THREE: Wrap up.</u>

How would you describe ME274 to a new student?
And
What recommendations would you have for them?

- What are the things that first come to mind when students describe this course? What do they perceive this course to be and how do they think their fellow students will view it?
- What aspects of the course and course environment do these students perceive to be useful or important? If anything?
- Maintain some of the topics about the semester as a whole, explore what recommendations the students would have not just regarding the course, but regarding the course as one smaller part of a whole semester.

EXAMPLE FOLLOW-UP QUESTIONS

Is there anything you wish you knew going into ME274 this semester? Why is that, can you give an example?
If a friend asked you whether they should take this course, what would you recommend?
If a friend asked you how to do well in this course, what would you recommend?
Do you believe that you will find this course to be helpful in the future? Do you believe others could benefit from taking this course?