Bringing Research to Practice: Exploring Applications of Resource Usage Research in Undergraduate Mechanics Education

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Introduction

Educational technology continues to redefine the ways in which engineering is taught through the introduction of new learning resources, online learning environments, and innovative approaches to presenting content in the classroom[1,2]. As the number and diversity of learning resources available to students expands, understanding how and why students use these resources is crucial to teaching practice[3,4]. With greater knowledge, instructors can empower their students to use these resources to their maximum benefit both inside and outside of the classroom. Unfortunately, understanding how students interact with their learning resources can be especially difficult in classrooms which blend traditional in-class instruction with digital resources and online interactions[5,6]. Although digital and physical learning resources have been researched extensively on a part-by-part basis, it is less common for studies to combine insights on many resources simultaneously. Therefore, it can be difficult for instructors to make informed decisions about how to integrate and apply these scattered research results to their own instructional practice.

There have been a variety of calls in the Engineering Education community to better translate research findings into innovative changes to educational practice and policy[7,8,9]. In 2008, when instructors at a Purdue University - West Lafayette (PUWL) decided to apply research-based methods in the redesign of their Dynamics curriculum, they encountered similar difficulties in translating research to practice[10]. These faculty members wanted to create a new resource- and technology-rich learning environment. However, while each component of the proposed classroom had its own robust body of literature, there was little existing research to help integrate these diverse methods into a single course.

Thus, these instructors relied on their extensive past experience as educational practitioners to guide an initial course redesign. The resulting curriculum, now referred to as the *Freeform* learning environment, was successful by many metrics. For example, grades in Dynamics improved as the percentage of students earning D, F, or W (withdrawal) grades in Dynamics courses declined significantly over the next few semesters[11]. As a result, our research team began to investigate how students experienced and navigated their new resource-rich learning environment. This examination of the *Freeform* experience has provided new insights into its affordances and barriers and their resulting impact on student success.

This research work continues to expand in scope and document new findings, which in turn have informed changes to instruction in the *Freeform* environment and the Mechanical Engineering (ME) department at PUWL more broadly. The purpose of this paper is to synthesize the findings of these previous studies, drawing connections between research and practice by using this ongoing evolution of Dynamics instruction as a context for discussion. In this paper, we address the following research questions:

RQ1: What can we learn from the synthesis of these various research methods and perspectives regarding students' use of learning resources in the *Freeform* environment?

RQ2: What changes, or proposed changes, have resulted from efforts to translate this research into practice in Dynamics courses and across the department of Mechanical Engineering?

After introducing the *Freeform* environment and the resources it employs, RQ1 will be addressed through a synthesis of five recently conducted studies on resource use both in Dynamics classes and in the ME department at PUWL. RQ2 will be addressed by extracting recommendations for educational practice we can discern from this synthesis, and discussing how those recommendations have translated to practice thus far.

Background: Educational resources and the *Freeform* environment

Since *Freeform* was piloted in 2008, it has evolved into a significant departure from how Dynamics was previously taught. Every aspect of the course, from its curriculum to its resources, have been redesigned to address a diverse range of student needs with the goal of improving students' academic performance, and their overall experience, in engineering Dynamics[10]. To accomplish this goal, the course designers created a number of learning resources combining a variety of educational methods including Active[12,13], Blended[3,14], and Collaborative[12,15,16] (ABC) learning, each of which had demonstrated positive effects on students' education and experience in prior research. These ABC methods scaffold the *Freeform* environment, producing an intentional alignment[17] in how course content is presented to students throughout their semester.

Unfortunately, while each of these ABC methods had been studied thoroughly in the past, little advice existed on how to combine best practices in ABC learning. Instead, research often focused on the effects of introducing single, isolated resources or adjustments to an existing course structure[18]. Therefore, when the introduction of the *Freeform* led to student success, our research team set out to improve our understanding of *Freeform* and its learning resources, while also contributing to a growing body of knowledge on complex and resource-rich learning environments. To accomplish this goal, we have focused our efforts on understanding how students use a set of nine, commonly employed support resources. This list includes a variety of digital, physical, and collaborative resources, and all are part of students' experiences in the *Freeform* environment. Table 1 below contains a brief description of each of these resources with citations to literature which has helped in their design or subsequent analysis.

In most of our recent studies, we have examined students' self-regulated learning using Help-seeking behaviors (HSB) theory as a conceptual framework[19]. Help-seeking behaviors refer to the ways in which students seek out assistance when they encounter difficulties while studying[20] and are distinguished into two types: adaptive, and non-adaptive (or expedient) behaviors[21]. Adaptive HSB is demonstrated when students actively seek help in understanding concepts or grasping methods. Students who demonstrate this kind of behavior seek out information to help them correct or develop their understanding of key concepts. These students empower themselves to not only find answers to their questions, but to understand how to deduce those answers for themselves[22]. Non-adaptive HSB is characterized by avoiding problems or by

seeking out assistance that does not contribute to learning. This could include asking for help when students are capable of solving the problem themselves, or seeking out answers to perform well on assessments and chase a higher grade[22]. Prior research has tied HSBs to self-efficacy[23], internal motivation[20], and course performance[21], as well as contextualized HSB theory in light of recent changes in educational technology[24].

Table 1: Resource List from the Freeform Environment

Freeform Course Resources	
Course Instructor	The instructor is the most prominent source of information during class meetings, often through lecturing or by answering individual questions. Instructors in the *Freeform* environment are encouraged to foster ABC learning by asking questions, interacting with their students, and facilitating group work, among other activities[12,25,26].
Course Lecturebook	The lecturebook acts as the *Freeform* equivalent of a textbook. It includes equations, derivations, example problems, and conceptual questions. There is also ample white space so that students may take notes or write-out solutions alongside the text itself, acting to foster student activity even during lecture[13]. Students may also use the lecturebook in conjunction with example solution videos posted on the course blog, facilitating Blended learning[3].
Peer Collaboration	Students can collaborate with their peers to obtain help when clarifying difficult topics that arise during class meetings[15,27]. Outside of class, collaboration can take place in-person or digitally including interactions through social media, organized study groups, or spontaneous interactions in public spaces such as the TA help room.
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. Office hours typically take place in the instructor's office on a first-come, first-served basis.
TA Help Room	The Teaching Assistant (TA) help room, similar to instructor office hours, allows students to go and request help from course TA's[28] at a predetermined location during a set schedule each week. However, the TA help room is open for a much larger portion of the week than instructor office hours.
Online Videos	There are a variety of videos provided through the *Freeform* course blog to aid in student learning[29,30] including worked solutions to examples in the lecturebook, solutions to homework problems, and video demonstrations of Dynamics concepts.
Discussion Forums	Each homework assignment and exam in the course has a corresponding discussion forum on the blog, where students are able to compare work, collaborate on assignments, and ask questions to clarify their conceptual understanding on the course content[31,32].

Extracurricular Resources	
Peers Outside of Dynamics	Prior observation has shown that students might ask questions of peers who have taken Dynamics previously. This could be considered collaboration, or could be treated similarly to asking questions of a TA.
Other Online Resources	These resources include YouTube and other online sources of information which are not directly affiliated with the course.

Recent studies on resource usage

Five papers on resource usage are included in this synthesis, some of which are still under review at the time of writing. Since research started in 2015[33], our team has collected a large dataset comprising transcript information, survey responses, video observations, and transcribed interviews from those students who consented to participate in this research. Four studies draw on data from the *Freeform* learning environment, while one comes from an analysis of department-level data. Each of the studies addressed slightly different questions related to the students' use of resources, covering everything from students' overall impressions of their courses, to detailed analyses of patterns in the students' resource usage behavior.

Resource usage and academic help-seeking in the ME department

A study by Wirtz et al.[34] combined two datasets with two corresponding methods of analysis: a quantitative Factor Analysis of collected survey data from 355 student participants, and a Grounded Theory analysis of 37 transcribed conversations (14 from individual interviews, and 23 conducted in groups). Each of these analyses identified and described the HSBs demonstrated by the undergraduate Mechanical Engineering students, as well as the students' perceptions of those resources. As a result of both analyses, Wirtz et al. found that the resources could be classified in one of two categories, 'detached', or 'anchored' resources. Detached resources had little to no constraints related to time, location, or scheduling, allowing students to freely engage with them when needed. Anchored resources had to be accessed at a certain time or place and often required some level of formality, allowing students to only use them within specific contextual limitations. Overall, detached resources were much more popular than anchored resources, and students often refrained from engaging with anchored resources until they had exhausted the detached resources available to them. However, the most popular resources were not necessarily perceived as the most useful, as many students reported that they considered anchored resources (such as instructor office hours) to be more useful than their detached counterparts (such as the lecturebook).

Student perceptions of the Freeform environment and its learning resources

The Thematic Analysis conducted by Kandakatla et al.[35] examined 28 student reactions to the *Freeform* environment and their perspectives on its learning resources. Students appreciated the broad range of resources provided for their use, expressing that the various sources of information allowed them to study at the time, location, and pace that best suited their preferences. Many students cited that the ways in which these learning resources integrated together (or made up for the constraints and limitations of one another) helped them to manage and navigate their course experience. This was especially true of the blended resources, which

could be used asynchronously. Using these blended resources, students were able to access detailed solutions and peer collaboration at odd hours of the day when they would otherwise feel forced to work on their own.

Barriers and motivators to students' engagement with learning resources

Evenhouse et al.[36] (pseudonym used for blind review) conducted a second Thematic Analysis of *Freeform* interview data. This study built on the work of Kandakatla et al. to examine the nuances of how, and why, students chose to interact with specific resources. While previous work had gauged students' perceptions of the environment as a whole, this study examined the priorities, motivators, and barriers which affected how students engaged with each of their learning resources. These results were also examined using HSB theory, making note of both adaptive and expedient behaviors. The most frequently reported barriers to student engagement were related to scheduling and timeliness, demonstrating how strongly students' perceptions of the course resources were influenced by the resources' availability. Students also gauged the relevancy of the information they expected the resource to provide. Repeated negative experiences with a given resource would cause students to view the information provided by that resource as less relevant and, therefore, less helpful to engage with, a finding consistent with prior HSB research[20]. This was especially true of collaborative resources, where mistaken or incorrect information provided by peers, or even the course instructor, could cause students to not engage with those resources in the future. However, students often reported a positive attitude towards collaborative and social resources, even when scheduling or personal preference had prevented them from using those resources themselves.

Clustering and evaluating patterns in students' reported resource usage

Stites et al.[37] (pseudonym used for blind review) performed a cluster analysis of *Freeform* students by surveying their reported resource usage habits. The 479 participants were sorted into nine clusters using a model-based approach, representing nine distinct patterns of resource usage. Stites et al. found that the averaged resource usage statistics were only representative of one of those nine clusters, indicating that averaged behavior could only represent the usage pattern of a small portion of the class population. The study also explored each of the nine identified clusters using a qualitative analysis of *Freeform* interview data from 44 interviewees. Stites et al.[37] found examples of adaptive resource usage from interviewees in each of the nine clusters, and in connection with the use of all nine resources listed in the study. Students reported focusing on a small subset of the resources provided (typically 2-4 resources) while overlooking the others, rather than consistently using all nine resources at their disposal. Four resources stood out as being most popular: peer collaboration, the lecturebook, online videos, and the course blog, which reflected the findings of Wirtz et al.[34] at the departmental level within the context of the *Freeform* environment.

Examining relationships between resource usage and academic performance

Using the cluster analysis from their previous paper, Stites et al.[18] examined how the nine resource-usage correlated with the students' academic outcomes in the course (i.e., a higher final grades and better exam performance). Combining survey data and academic transcript

information, they found that the resource usage patterns were in general not significant predictors of course performance. However, one cluster (those who primarily used the lecturebook and collaborated with peers), showed slightly better course performance as compared to other clusters, even after controlling for prior academic performance. The key implication of this study is that there are many resource-usage patterns which can lead to student success. Rather than recommending that students adopt a specific resource-usage pattern, instructors should encourage students to foster help-seeking behaviors that maximize the benefit of their preferred resources.

Synthesis of literature on resource usage

Each of these studies were conducted by researchers from the same research team. Through the comparison of findings across their many research questions, datasets, and methods of analysis, we can synthesize a number of useful observations about the experience of students in *Freeform* classes.

Determining resource popularity: Convenience is king

The most common theme in each of these studies was how strongly students preferred to use resources that were immediately available when needed. Students used resources that could provide them with answers quickly and easily far more than resources that required them to wait for a response (such as the course blog), or to travel out of their way to engage in a collaborative dialogue (such as office hours)[37]. To use the terms from Wirtz et al.[34], students were much more likely to report that they used detached resources while studying, only turning to anchored resources when they could no longer help themselves using the resources close at hand.

However, the resources which students used the most, were not necessarily the resources which they considered to be the most helpful. Tutoring from TAs and instructor office hours proved to be especially difficult for students to access due to their physical location on-campus and limited scheduling options[36]. However, students perceived these resources to be very useful as sources of help[34], and frequently encouraged their peers to engage with them[36]. Unfortunately, using these resources involved overcoming tangible barriers to engagement caused by location and scheduling, barriers which dominated these students' interview discussions about engaging in collaborative work. Some students took the time to overcome these difficulties, such as students who went out of their way to study near their peers in public spaces, but these were the exceptions. Most students were content to engage asynchronously with their peers through discussion online[35], or opted to use more detached, readily available resources[34,36].

Collaborative resources: Valuable and frustrating

Across these studies, students cited frustration with their perceived lack of access to valuable resources due to scheduling constraints or other barriers. Many students reported that the blog's online discussion forums, the instructor's office hours, or other opportunities for collaboration would be more useful to them than simply reading the lecturebook or watching example videos[34]. This was true even when students had little experience engaging with those resources themselves, either due to personal preferences or in response to barriers to their

engagement. Students who could not engage in collaboration due to a lack of community engagement (i.e., a lack of posts and responses on the blog) or scheduling conflicts felt as though they had lost a potentially valuable resource due to circumstances beyond their control[36].

However, there were also situations in which students became frustrated with the resources themselves, rather than constraints due to timing or scheduling. Negative experiences with, or perceptions of, an instructor or peers could cause students to lose trust in those people as resources[36]. This lack of trust could then act as a source of frustration and a barrier to engagement. The tragedy of these situations was that students still perceived these collaborative resources as potentially helpful[34], and frequently recommended that future students in the course use their instructor and peers as sources of help[36].

Diverse perspectives and approaches to help-seeking

While convenience was a dominant factor in the students' experiences with, and usage of, *Freeform* resources, students interpreted convenience in many different ways. For example, students who routinely completed their homework early were likely to view the online discussion forum as a less-valuable, anchored resource, simply because they chose not to wait for their peers' feedback to come trickling in over time[34,36]. Others appreciated how the asynchronous nature of the blog allowed them to study on their own time[35]. For these students, the inherent time-delay between posting questions and receiving answers was a small price to pay for being able to engage in collaboration at odd hours or in off-campus locations[35,36].

However, student-by-student variations were not limited to differences of opinion. After choosing to engage with a set of resources, different students could use that same set of reported resources in vastly different ways. Evenhouse et al. discussed how students demonstrated a variety of HSBs when engaging with the online discussion forum; some actively participated in the blog, while others simply read through the comments looking for answers to their most immediate questions[36]. In such cases, it may be more important to assess and capture the HSBs and motivations demonstrated by students, than to determine what specific sources of help they engaged with[34,36]. The cluster analysis of Stites et al.[18,37] seems to support this notion; success is less about what resources students use, and more about how and why they use them.

The many pathways to success in a resource-rich learning environment

Students in the *Freeform* environment expressed a collective appreciation for the variety and shear number of learning resources available to them[36], how the resources supplemented and integrated with one another[35], and how the design and content of the resources aligned with the rest of the course[36]. Having this breadth of resources resulted in these students demonstrating a variety of different study strategies[37]. Yet even when students chose their study strategies based on personal convenience, the students' patterns of resource usage proved to be largely insignificant as predictors of higher grades in the course or on exams[18].

Analysis showed little connection between the study strategies that students reportedly employed, and how they went on to perform in the course. This seems to indicate that students could engage with *Freeform* resources according to their personal preference and still find the

help they needed[18,35]. Considering their earlier findings that adaptive HSBs were evidenced across all of the nine clusters representing resource-usage patterns[37], Stites et al. reflected that it may be more useful for instructors to foster adaptive HSBs in students, rather than pushing students to adopt specific resources or study strategies[18]. In short, both quantitative[18,37] and qualitative[35] studies indicate that there are many ways for students to find success while studying in a resource-rich learning environment.

A cautionary note on the "typical" student

The cluster analysis by Stites et al.[18,37] demonstrated how potentially misleading it can be to speak in generalities about the popularity and use of specific resources. Although looking for norms and themes can be informative, Stites et al. showed that the averaged levels of resource usage (those taken to represent a "typical" student) are only representative of a small portion of the overall class population: that one cluster of students whose usage pattern aligns with the average[37]. Although students engaged more readily with convenient, detached resources before moving on to use anchored and collaborative sources of help[34,35], it is important to keep in mind that this theme comprises a broad range of study habits and preferences that students expressed through their work. Stites et al. showed that most *Freeform* students focused their attention on a small subset of course resources, rather than distributing parts of their attention across all nine resources as an average would imply[37]. These results together illustrate how taking an averaged view of resource usage masks the full diversity of student experiences, potentially leading instructors to make decisions about how to help their "typical" student, while actually serving only a small portion of the class population.

Discussion: Translating research to practice

In light of these various findings, our research team has developed a number of recommended changes to the ABC instructional practices used in *Freeform* classrooms. Some of these recommendations have already been put into practice at our institution, while others have inspired future development of the *Freeform* environment and its resources.

Break down barriers to timeliness and scheduling

Arguably, *Freeform* students' greatest priority when selecting resources was their own personal convenience. This could also be seen in the ME department as a whole, where students preferred detached resources which could be accessed at their leisure, as well as in the *Freeform* dataset. Thus, finding ways to mitigate or eliminate student barriers to engagement due to scheduling conflicts or poorly timed feedback should be one of the research team's top priorities moving forward.

Although it has been mentioned in previous work[33], our first step to improve the experience in *Freeform* was incorporating an online application for collecting homework and providing rapid feedback to students. Interviewees frequently cited how the timing with which they received feedback affected how useful that feedback was for their studies. Given how much students appreciated having a wealth of resources at their disposal, we deemed it important to make sure that students could receive feedback on submissions in a timely manner. In addition,

our prior video analysis of in-class instructor actions[38] revealed that a non-trivial amount of class time was being consumed by administrative actions, such as returning students' homework. Employing an online grading application removed the need for physically handing back homework and allowed students to receive feedback in a timelier manner. As a result, this solution has since spread throughout the ME department and is currently in use in dozens of undergraduate courses.

Organize resources to enhance visibility and ease of access

Resources could not only be anchored by a specific time or schedule, they could also be anchored to a specific place[34]. In the end, students were far more likely to engage with easily accessible resources than those they had to go out of their way to interact with. Taking steps to position sources of help in more public environments, or redesigning user interfaces to allow multiple resources to be visible at once, could make all the difference when trying to encourage student engagement.

One of our ongoing experiments involves moving instructor office hours to a public location (not the instructor's office) and staggering the timing of each class sections' office hours over the course of the day. During interviews, many students expressed frustration about being unable to attend office hours, despite survey data showing that very few students attend office hours in the first place. This semester (Spring 2019) instructors of Dynamics decided to approach the concept of office hours from a new perspective, conducting them in an easily-accessible public location at differing times for each class section, all while encouraging students to attend whichever office hours fit within their schedules. At the point of writing this paper, we have not had the chance to conduct any formal data collection to examine the effects of this change, but the anecdotal accounts have been remarkable. "I've been keeping track…" one of the instructors reported after the first week of class, "…I've had 22 kids come to office hours in the past two days." Another instructor reported that as many as 40 students attended their office hours in the first week, making one week's worth of attendance comparable to an entire semester's worth of office visits in previous years. Although it is still the start of the semester, current feedback indicates that changing to a more informal, loosely-structured approach to office hours has drastically increased student engagement. We will continue examining the effects of holding office hours in this manner through interviews and data analysis, investigating what new affordances and constraints have resulted from these changes.

This research has also inspired a number of changes to how the *Freeform* course blog operates. In the past, the blog layout was broken up by the components of the course. In this way the students' homework was available through one menu, solution videos through another, demonstrations through yet another menu, and so on throughout all the course's digital resources. Most interviewees reported that, when they accessed the blog, they only went to the 'Homework' tab where their assignments were provided, largely ignoring the rest of the website[36]. This resulted in many students skipping over the various demonstrations and simulations provided on the blog. Some students didn't even realize that such demonstration videos were available. Our team addressed this discrepancy by seeking out contacts in the User Experience Design program at our institution, seeking insight on how to better organize our online resources to improve both visibility and ease of access. As a result, we are developing a

new version of the course blog which combines the course resources together by topic, as well as exploring additional ways to improve the overall accessibility of the website.

Foster trust and engagement in collaborative resources

When students were confused or conflicted after engaging with a given resource, they often lost trust in its ability to provide them with the help they needed. This was especially true when students encountered problems with using collaborative resources such as the discussions on the course blog, which resulted in them avoiding potentially useful opportunities for peer collaboration and expert advice. The need to provide students with trustworthy information and positive collaborative experiences has inspired a number of current and future changes to the course blog, as well as highlighted the role of the instructor in facilitating positive experiences through in-class collaborative learning.

On the blog, students reported having difficulty identifying trustworthy information. Many students reported getting effectively lost in the variety of different responses that could be posted on a single question. To better enable students to filter posts on the blog, *Freeform* instructors have now implemented an upvote/downvote system, similar to what can be found on many social media platforms. This allows students to self-evaluate their own online discussions, introducing a way of identifying trustworthy information without needing an instructor or TA to evaluate the student responses. Instead of policing the blog, the instructor can focus on encouraging blog participation, a practice which facilitates both more posts, and more feedback on what posts are useful.

However, the instructor's role in encouraging engagement with collaborative resources is not limited to simply raising awareness of the resources themselves. Through this research, we saw how the experiences which instructors foster in-class can have a profound effect on students' willingness to seek help outside of the classroom environment. For example, students who were frustrated by in-class interactions tended to stay away from resources such as office hours and out-of-class peer collaboration[36]. Likewise, the cluster analysis showed that, although it is likely self-defeating to label any specific study strategy as 'the best', it does seem that students who engage in peer collaboration outside of class are predicted to perform slightly better on Dynamics coursework overall[18]. Combined, these findings highlight the importance of the collaborative activities which instructors bring into the classroom. In our work, facilitating positive experiences within the class community was an essential part of encouraging students to engage with their collaborative learning resources.

Remember, there are many pathways to student success

Despite the wealth of information on how individual resources can improve student performance, we found that in the resource-rich environment of *Freeform* there can be many avenues to academic success. There were few statistical differences in student performance based on their reported pattern of resource usage. Likewise, different students could interact with the same set of resources in vastly different ways. Moving forward, we will be placing more focus on helping students to develop adaptive HSBs, rather than simply highlighting the importance of using specific resources. Prior research has connected adaptive HSBs to

developing rapport[28], supporting self-efficacy[22], and encouraging internal motivation[20]. As was shown in the cluster analysis, students from each cluster could demonstrate adaptive HSBs, and cases of adaptive HSBs were found involving each of the nine resources included in the analysis. Motivating students to make the best use of their study time through adaptive help seeking has the potential to positively impact student performance[21], while still allowing students the freedom to study according to their personal preferences. Our next steps in planning the future of *Freeform* will draw on previous HSB publications in the Blended Learning space[24,39,40] as we explore how to facilitate a more positive and adaptive learning experience.

Finally, in addition to enjoying the sheer number of resources at their disposal, interviewees expressed an appreciation for the alignment and integration between the various resources in the *Freeform* environment. Now, this alignment is expanding a step further, as instructors in the ME department are applying these same instructional methods across the full scope of their undergraduate mechanics curriculum. Course developers and researchers are taking steps to redesign the courses in Statics and Mechanics of Materials, applying the ABC teaching practices and research-based insights developed in the *Freeform* environment. Their eventual goal is to provide students with access to a diverse range of ABC inspired resources across the full breadth of their education in engineering mechanics topics.

Conclusion

In this paper, we synthesized our findings on how students in Dynamics utilized resources to help them study in an Active, Blended, and Collaborative learning environment. Students tended to engage with resources that were readily available, prioritizing personal convenience even when they considered less convenient resources to be more useful. Analysis also showed that students can demonstrate adaptive help-seeking behavior while using any resource, and that there were few statistically significant differences in performance related to any specific resource usage pattern. Using the findings from this synthesis, we proposed four recommendations for instructors in the environment being studied, and discussed how these research-based recommendations are being translated into changes to teaching practice.

Each of the resources and aspects of the *Freeform* environment discussed here have been subject to research in their own right. Although this work provides a glimpse into how students interact with and balance these educational methods when they are combined into a single environment, there is still much more that can be learned about these resources and the contexts in which they are applied. Although each learning environment will be different, we hope that what we have learned regarding the availability, accessibility, relevancy, and efficacy of these resources can go on to further alter instruction locally, as well as inform the education of undergraduate Mechanical Engineers in other resource-rich contexts.

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