Exploring Literature on how Instructor Feedback Impacts STEM Student Motivation

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Abstract

This theory paper submitted to the Faculty Development ASEE Division will organize and frame literature around feedback and research related to the impact of feedback in engineering courses. Student learning is monitored, informed, and measured by instructors using a variety of instruments and methods that have been developed, iterated upon, and improved through educational research. One classroom practice that has been shown to be beneficial to students is providing appropriate feedback. This paper will explore what is known about the impact of feedback on student learning and how that research is being applied in an engineering education setting.

This literature review was used to create a conceptual model of feedback's role and impact in an engineering classroom and will inform future research exploring the relationships between feedback, how students perceive and act on feedback, and how these perceptions and actions related to given feedback can be explored using motivational theories. This literature review and model relating feedback to its impact on student motivation will be presented through a traditional lecture with the hope of informing practicing engineering educators of positive and effective methods of feedback that can be utilized in an engineering classroom to improve student learning.

Introduction

Feedback is built into every engineering course. It can be as straightforward as receiving grades on assignments, exams, or a final course grade. Feedback has been shown in multiple educational settings to be important and impactful to student learning through deeper content understanding, improved retention, and better student experiences [1]. By giving students feedback, a communication line is opened between the instructor and the student. Students are better able to adjust and correct misconceptions, recognize their strengths and weaknesses, and set personal learning goals [2]. Feedback has been identified as beneficial and having a positive impact on student learning in many educational environments through a variety of meta-analysis studies that are compared and contrasted in a paper by Hattie and Timperley [1]. This meta-analysis paper aimed to define feedback based on the contexts that it has been studied in and categorize feedback into levels based on what information was being provided to the learner. Although this meta-analysis showed that feedback has been widely researched and proven as an effective tool to improve student learning in multiple contexts and education levels, less is known about how feedback impacts the student beyond their ability to learn content, such as how they perceive and react to feedback. Research exploring student perceptions and preferences in feedback received has been situated primarily in writing courses [3], [4] with some additional notable research in second-language settings [5], [6] and general college settings with no specific discipline or specialization identified [7]. This existing feedback research has started to provide insights into how students react to the various forms of feedback they are given throughout a course experience, but these student reactions are all framed and studied in the contexts of the courses and content being taught and graded. Little is known about how students react to different types of feedback received throughout their entire course experience and how that

feedback impacts their choices regarding their engagement with the course content moving forward.

Purpose

The purpose of this literature review is to examine various ways in which feedback has been researched in engineering. This paper examines what research has been conducted and subsequent knowledge has been disseminated regarding feedback, as well as its use in science and engineering course settings. This literature review builds the foundations for a conceptual framework that can be used to investigate feedback's impact on student motivation in a college engineering classroom and how feedback given to students can be leveraged as a learning and motivational tool.

Scope

The scope of this literature review includes feedback utilized in classroom settings, specifically those that focus on teaching components of a typical engineering curriculum. A broad definition of feedback is: "information provided by an agent regarding aspects of one's performance or understanding" [1, p. 81]. While this definition is very broad and not specifically situated in an educational setting, Hattie and Timperley go on to say the following when feedback is situated in a formal education setting: "[For an] …instructional purpose, feedback needs to provide information specifically relating to the task or process of learning that fills a gap between what is understood and what is aimed to be understood" [1, p. 82]. For the purpose of this literature review investigating feedback practices and research in engineering education settings, the latter definition is more accurate to what this literature review will encompass. Researchers and practitioners alike have varying opinions of what feedback to students looks like, as their own perceptions can range from a letter grade on an assignment to extensive comments and recommendations based on student work [2]. This literature review includes a variety of forms of feedback in educational settings from various sources in order to best capture the impact that feedback may have on students in an undergraduate engineering classroom.

Research Questions

This literature review will compile knowledge regarding feedback from a variety of educational sources, as well as research in engineering education related to feedback given to students and what the outcomes were. This work lays the foundation for a future conceptual framework that will be used to address the following research question: *How does feedback provided to engineering students impact their motivation to learn course content and persist in a course?*

Methods

Although this literature review is not a systematic literature review, Borrego, Foster, and Froyd's [8] paper outlining guidelines for conducting a systematic literature review provided insight into how to find and select relevant books and scholarly articles included in this review. Key search terms used included "feedback" and "instructor feedback" in conjunction with "engineering class", "engineering course", and "engineering student". This search resulted in articles related to feedback in general educational settings and research in feedback practices in engineering. Literature resulting from this search is synthesized and discussed in the following section.

Results

The results of the search included a variety of books, journal articles, and conference proceedings for best-practices in feedback as well as research on feedback in engineering course settings. The results are presented in a way that highlights higher level theoretical constructs of feedback developed by education researchers and then gives examples of research in engineering course or content settings related to those constructs.

Feedback can be defined broadly as any information provided regarding performance or understanding, but it can also be applied more specifically to instructional contexts by specifically relating it to improving learning and addressing incorrect or missing content [1]. Feedback serves multiple purposes, as it is primarily a way for instructors to address misconceptions or gaps in knowledge with learners. However, Nicol and Macfarlane-Dick [2] point out that feedback, when used properly as a teaching and learning tool, can lead to more than just a dialog regarding content and learning; it can also help students begin to develop their own techniques for reflecting on and self-assessing their own learning and increase their self-esteem and positivity regarding learning. This source also points out that instructors benefit from taking time to provide quality feedback to learners, as they can use that as an opportunity to identify common gaps or misconceptions that may impact how they address topics and content in future lessons [2]. Affecting deep, impactful change in students from feedback provided is not common to all forms of feedback. Best practices regarding feedback, such as feedback being timely and targeted, have been identified [9]. When these best feedback practices are used in conjunction with one another, they positively impact student learning in a way that a simple assessment or test letter grade cannot [2].

Rucker and Thomson [10] note in a publication that the past three decades of research in feedback has led to the discovery of key constructs that relate to the instruction and academic settings. The next sections will discuss those key constructs and how they are used in STEM and engineering research and education settings.

Who receives feedback and who gives feedback is important to how it is perceived and what actions may follow after it is delivered to students. Those who receive feedback are likely trying to draw value from feedback, as they view these feedback interactions as an open dialog about their learning [2]. Equally as important is who is giving feedback. In classrooms, depending on the assignment or activity, feedback could come from the instructor, a teaching assistant, or a peer in the class. Engineering students have shown to be responsive to corrective feedback from instructors [11], engaging with feedback provided to them on draft papers or assignments by viewing feedback and turning in updated drafts with better scores and less mistakes. However, in one study published, graduate teaching assistants providing technical writing feedback to engineering students were found to be inconsistent in the amount of points deducted. They were not consistent in which answers were acceptable and unacceptable, overly specific at times, and had an authoritative tone that was not perceived positively by students [12]. There is no single best source of feedback, as different sources have different perspectives and levels of expertise/relatability to offer. Although peer feedback is beneficial to students both giving and receiving the peer feedback [13], [14], in some cases students recognize that peers do not have the knowledge or expertise to provide useful and valuable feedback to one another, and those students are more inclined to seek feedback from an instructor [15]. Many times, who provides the feedback is also dependent on context of the learning and resources available in that context. Moore [16] presented a peer feedback approach that that was focused on getting

students feedback through their peers simply due to the volume of students in the course and the task that it would be to provide them all with meaningful feedback otherwise.

Content of feedback provided to students is arguably the most important component of feedback. In order for feedback to be as useful to students as possible, it needs to be directed at a clear goal, descriptive in nature, and actionable [9], [10]. Hattie and Timperley [1] frame feedback as falling into one of four categories related to the content: task level feedback, process level feedback, self-regulation level feedback, and self-level feedback. Task level feedback is the simplest and most straight forward type of feedback and only delivers content to the learner regarding if or how well tasks were performed. Process level feedback is the next level of feedback and focuses more on the procedure needed to complete the tasks that were addressed in the task level feedback. This feedback content is the most beneficial that a student can receive from an instructor because it focuses on the organization of new knowledge and less on the final result. The third level of feedback is related to the student's ability to self-regulate their own learning through self-reflection and self-evaluation. These abilities are what Nicol & Macfarlane-Dick [2] emphasize as the ultimate goal of their recommended feedback practices. The final category of the content of feedback as defined by Hattie and Timperley is self-feedback [1]. This is feedback that speaks to qualities of the learner as a person, and does not focus on the content of what was being learned.

Mode of feedback given to students relates to how feedback was delivered. For instance, feedback can be given in either a structured or unstructured way [17]. Structured feedback could be explained as receiving feedback through a rubric filled out by the instructor and officially returned, whereas unstructured could be receiving feedback orally in passing in a hallway outside of class. With technology being used in engineering classrooms more frequently, the mode with which feedback is delivered has transitioned to being primarily digital. Feedback can now be given through email or a school's learning management system. Online feedback to students has both benefits and drawbacks. In one study, online feedback was provided to students' technical writing material and the opportunity for corrections was given. Although the online tool used to provide feedback had a variety of features to communicate different comments or suggestions on student work, the results of the research study showed that students utilized the in-line instructor comments significantly more than the other tools that were available, primarily for the speed and ease of access [11]. Increasing students' accessibility to feedback through use of learning management systems or other digitally-based platforms would be considered beneficial in any classroom, but by utilizing alternative modes of feedback communication on learning management systems, the instructor potentially limits their ability to facilitate open dialog about the content and any misconceptions present in person with students. Quite often the mode of the feedback is impacted by what is being given feedback on. One instance in which electronic feedback has shown to be useful is when grading CADD graphics assignments [18]. By utilizing tools in the CADD software designed for communication across users, feedback can be provided, saved, and archived. By electronically tracking the feedback given to students, the instructors have a digital log of common misconceptions and mistakes of students that will better inform their teaching practices in future lessons.

Occasion of feedback related to when feedback is received compared to when the task was completed. Research that reports effective feedback practices consistently speaks to the importance of learners receiving feedback in a timely manner [1], [2], [9]. The sooner student misconceptions or shortcomings are addressed and corrected, the more effective the feedback

will be in improving student learning outcomes. For example, one study looked at an engineering class that was split into two groups that were both given similar e-assessments on technical course content [19]. One group was given feedback through the e-assessment after the entire problem set was completed and submitted, while the other group was given feedback on each individual question and had unlimited attempts to correct each question. This study found that the students who received unlimited attempts and immediate feedback were more successful on the summative examination than students who received less prompt feedback with no change of correction [19].

Each component of feedback outlined above plays an important role in how students receive and act on feedback to better their learning in a course, and when combined effectively these constructs have been shown to be effective in STEM and engineering classrooms based on the research discussed in each category relevant to feedback.

Discussion

The need for feedback to calibrate learning and knowledge organization is salient for any subject, topic, or task. Without the ability to clearly communicate when learners have incorrect information, misconceptions, or misalignments between ideas, learning quickly becomes ineffective. Although feedback can be provided to students in multiple ways when considering the questions of *who*, *what*, *where*, and *when* with regards to its delivery, it has the responsibility of providing learners with an opportunity to act on the feedback that is given. Without the ability for learners to take that feedback and leverage it for an improved or deeper understanding of content [1] and regulate their own learning [2], it would not be impactful to their learning. The literature collected and reviewed above can be synthesized into the model shown in Figure 1.

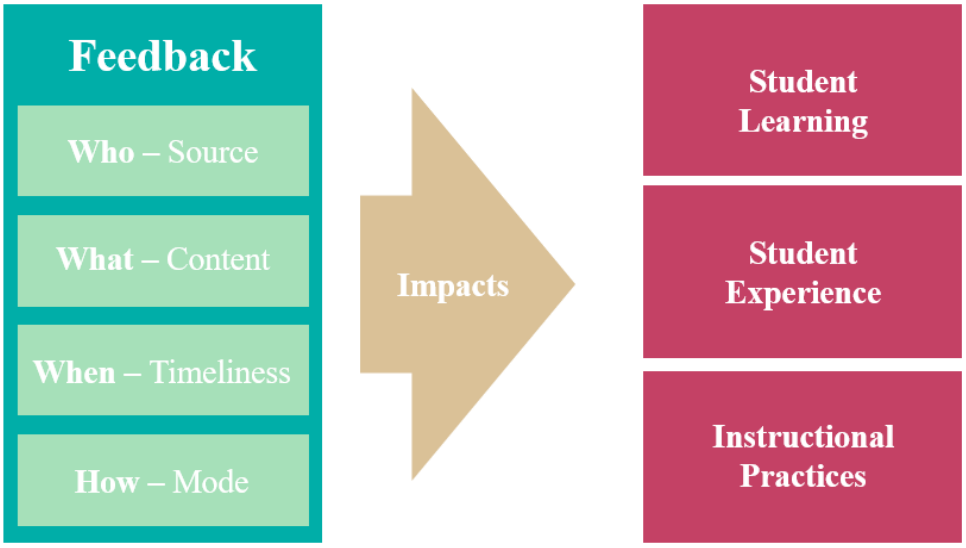

Figure 1: Model of Feedback's Impact in an Engineering Classroom.

What is still uncertain after this literature review is how engineering students 1) perceive feedback and 2) choose to act (or not act) on feedback provided to them. What feedback encourages a response in which a student may aim to correct their own misconceptions and misunderstandings? Alternatively, what feedback elicits a negative reaction towards the content

or the instructor? The students' perceptions of feedback they receive impacts the next steps they take with regards to the material being learned. One case study started to explore these questions in engineering students [20], but does so with only one group of students doing specific math related tasks. This research showed that engineering students placed more value in the teaching assistant feedback, but did this because the teaching assistant controlled the grades, not because that feedback was more helpful than the peer feedback received [20]. Continued research exploring student reactions to various types of feedback and how those reactions inform future actions of students will provide insight into instructor and teaching assistant feedback practices in educational settings.

Student perceptions and subsequent responses to feedback based on their desire to improve their own learning could be explored through motivational theories. When related to education, a student's motivation to learn is reflected through their engagement and contribution to the learning environment [21]. Feedback is primarily a form of communication between instructors and students, and this communication, along with its potential impact on students next actions and decisions regarding the material, aligns well with some motivational theories and their constructs. For example, self-determination theory (SDT) is derived from the ideas of intrinsic and extrinsic motivation theory [22]. This theory states that people want to grow and change and improve in their life and can be motivated to do so by three different needs: relatedness, competence, and autonomy [22]. Feedback fits into this specific theoretical lens well, as feedback 1) provides a connection between the learner and the instructor or peer who is providing them feedback, which can foster a sense of relatedness, 2) aids in competence development on a topic through the correction and calibration of information, and 3) encourages students to be autonomous and independent learners by leveraging good feedback practices to help develop self-regulation of learning. Researchers have found that engineering students who experience higher levels of self-determined motivation indicate that their needs were met in the course [23]. When feedback can be used as a way to meet student learning needs, students will draw positive motivation from feedback they receive. This positive motivation will impact the choices they make with regards to how they utilize that feedback to enhance their learning and course experience. This addition of a motivation component to the model of feedback in an engineering classroom is shown below in Figure 2.

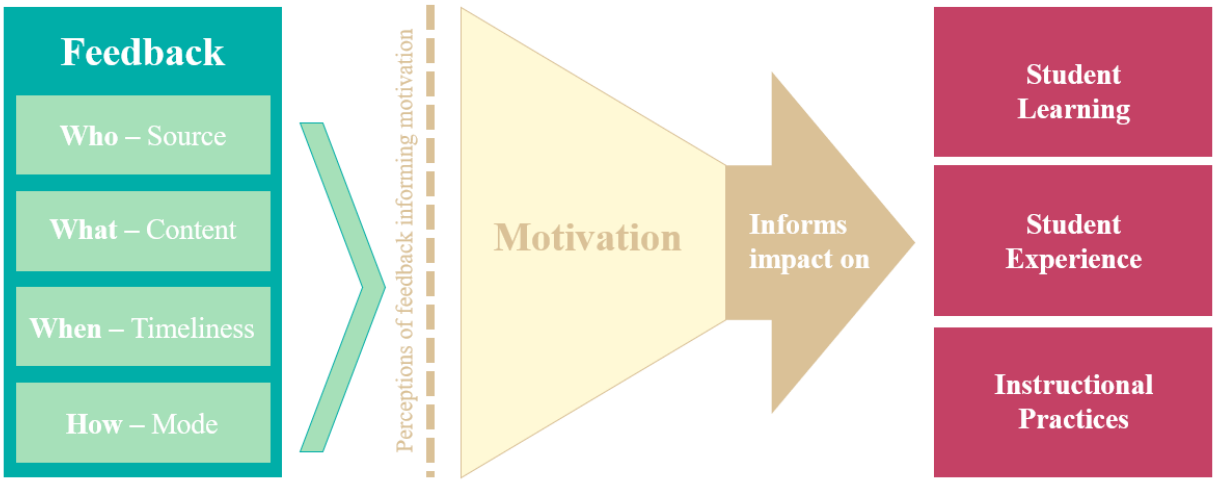

Figure 2: Model of Feedback and Motivation's Impact on an Engineering Classroom.

Conclusion and Future Work

The purpose of this literature review was to review feedback, its impact on learning, and how it is being used and researched in engineering courses to further students learning. The results of the literature review proved useful, as research on feedback in educational settings has shown that feedback can be used to improve student learning through better knowledge organization and retention, as well as improving student experiences in courses through the use of peer and instructor feedback cycles. Although there is no one single "best practice" for giving feedback to students, various constructs impact the quality and usefulness feedback, such as when and who delivers feedback. Providing feedback that evokes a positive improvement to the engineering student learning experience will increase the motivation of engineering students to learn course content and subsequently produce engineers with more complete technical and non-technical competencies.

Future work related to this literature review will involve further development of the model of the impact of feedback in an engineering classroom. This model will inform the theoretical lens chosen to investigate student perceptions of feedback and how those perceptions inform students' subsequent actions related to using feedback. With insight into how engineering students perceive feedback and act on it, engineering education practitioners will then be able to make informed decisions regarding which feedback practices to employ in their own courses. Further development of this model and research will shed light on what feedback practices improve engineering student learning and positively impact student learning experiences in college engineering courses.

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