Student and Faculty Perceptions of Standards-Based Grading in Undergraduate Engineering Courses

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Introduction

Standards-based grading (SBG) is an alternative grading approach that places focus on evaluating students' mastery of course learning objectives, rather than using the traditional 0-100% scale. Unlike traditional grading systems, SBG aims to provide more clear expectations about what students should know, as well as clarify their progress towards each of these outcomes. Implementing SBG has been shown to improve students' focus on mastery and learning [1], including in engineering courses [2]. Previous work has shown that faculty perceive that SBG provides benefits such as more direct feedback to students, improving students' abilities to self-assess, and a greater focus on learning [3]. This study aims to expand upon this existing work about the benefits of standards-based grading by interviewing both students and faculty in two engineering courses that use standards-based grading to explore how the instructor perceptions of student experience compares to the actual lived student experience. Because the students and instructors are affiliated with a program that uses other additional forms of alternative grading – such as grading on a five-point scale [4], these interviews also allow for a better understanding of which of these perceived benefits are specific to SBG, and which are more general to alternative grading in general. By parsing apart which elements are specific to SBG and which elements are general to other alternative grading practices, specific recommendations can be made for those implementing SBG and for those implementing other alternative grading schemes.

Background

A variety of alternative grading strategies (e.g. standards-based grading, specifications grading, ungrading, mastery grading, and contract grading) are becoming increasingly popular across university courses in science, technology, engineering, and math courses [5]. Although these methods vary, four pillars for alternative grading were developed to describe the key elements that are common across alternative grading strategies. These pillars include clearly defined standards, helpful feedback, marks indicating progress, and reassessment without penalty [6]. Standards-based grading (SBG) is a specific alternative grading strategy that awards grades based on how many learning objectives (or standards) have been met. SBG has been implemented in a variety of engineering courses including Signals and Systems [7], Circuits [8], Fluid Mechanics [9], Thermodynamics [10,11], and Engineering Design [12]. SBG meets the four pillars of alternative grading by identifying a clear list of standards, providing feedback to students that communicates if they have met each standard or not, assigning a grade based on the number of standards met, and allowing students to continue to reattempt to meet each standard – rather than just getting a low grade and moving on without learning the topic [13].

Previous work has been done to identify both student- and faculty-identified benefits and challenges of SBG within university engineering education using surveys [3,12,14]. Example benefits include a focus on learning, opportunities for self-directed learning and assessment, and a focus on improvement. Example challenges include lack of transparency, no partial credit, and more effort required. To further understand the student experience in these types of courses, this project consists of interviews with students and faculty from two SBG courses. The interview process allows the researchers to dive deeper into the details of the student experience, and the inclusion of both faculty and students from the same courses allow for comparison between faculty perceptions and student lived experiences within the same course.

Methods

This study consisted of interviews with students and faculty from two different courses: Circuits and Fluid Mechanics. Each of these courses is described below in the context of the four pillars of alternative grading: *clearly defined standards, helpful feedback, marks indicate progress,* and *reassessment without penalty.*

Course Structure - Circuits

Circuits is a 3-credit course that covers circuit laws and solving strategies. In this course, each of the 3 credits was framed as a different component of the course; credit 1 focused on DC circuits, credit 2 focused on AC circuits, and credit 3 focused on extending knowledge through a "choose your own adventure" component. Twelve fundamental principles of circuits were identified: electrical properties (voltage, current, and resistance), effective resistance, Ohm's Law, power, Kirchhoff's Voltage Law, Kirchhoff's Current Law, node voltage method, mesh current method, voltage division, current division, Thevenin/Norton Equivalents, and superposition. For each of these twelve fundamental principles, two *clearly defined standards* were identified: describing the fundamental principle and applying the fundamental principle. Students met the describe standard by creating a one-page "Describe Sheet" that included a description, relevant formulas, applications, etc. Students met the apply standard by earning at least a 4/5 on a quiz that tested understanding of that principle. These tokens needed to be earned by all students, and those standards were chosen to prepare students for other courses that required those concepts as prerequisite knowledge. Other tokens could be earned through Professionalism tokens (e.g. turning in notes, attending class, and turning in assignments on time), as well as completing "choose your own adventure" activities (e.g. Fundamentals of Engineering practice exams, challenge problems, and projects). Although these activities helped students grow in their learning, they were not deemed required to pass the course. If a student completed all of the required standards, they earned a C. Earning additional tokens increased their grade.

A token tracking spreadsheet was created to show students their token progress, and the number of tokens they had earned translated to a final letter grade in the course *(marks indicate progress)*. An example of a token tracking sheet can be found in Appendix 1. In addition to the

token tracking sheet, *helpful feedback* was provided through instructor comments on the assignment in the learning management system. If students did not earn a token, the comment included what should be fixed to earn the token. Students could resubmit their "Describe Sheets" or retake quizzes as needed to earn their token (*reassessment without penalty).*

Course Structure - Fluid Mechanics

Fluid Mechanics is a 1-credit course that covers six fundamental principles: Bernoulli's, Conservation of Mass, Drag, Archimedes', Impulse-Momentum, and Pressure-Fluid-Height. For each of the fundamental principles, the students, similarly to circuits, needed to complete a "Describe Sheet" that included a word description, applications, sketch, equations and units, and connections to other learning. Students also needed to complete six "Define Sheets" for six relevant concepts in the course, giving a description, sketch, and equations and units. Five of these topics were prescribed (i.e., Specific Weight, Specific Gravity, Total Pressure, Head Loss, and Flow Rate) and one was a student choice. For Describe and Define Sheets, students needed to get at least 70% or higher, meaning there were no misconceptions on the sheets. Students also had quizzes each week to assess their understanding, which they needed to get at least 80% on. Since the course was in a flipped-classroom format, students would watch videos each week and take notes with a requirement to include at least two questions. These three deliverables were the required tokens designated with *clearly defined standards* and considered the baseline of understanding for Fluid Mechanics to carry into future courses. Other tokens included homework problems, reflective learning journals, video note question revisits, time tracking sheets, and in-class activities. These were considered helpful to be successful in the required tokens, but were not considered required to pass the course.

In addition to the required tokens for the aforementioned deliverables, four other required larger deliverables were calculated into their grade: a deep learning activity (DLA), a written exam, a verbal exam, and a professional conduct score. The DLA was spread throughout the course with weekly deliverables to help them complete it. It was a project focused on modeling a tank draining using Bernoulli's and the Conservation of Mass. This was done using both experimental and theoretical understanding. The professional conduct score is where they self-assess themselves on quality of work, engagement in class, communication, and timeliness. This is then discussed with the instructor to come to a consensus on a score for that portion of their grade, with a focus on goals moving forward based on their professional conduct in Fluid Mechanics.

All of these deliverables mentioned above, required and not required, were displayed to the students on a token tracking spreadsheet (*marks indicate progress)* where they could visually see their progress in each of the weekly modules as well as their grade progression based on the number of tokens completed and the score on the larger deliverables. There were virtual "stickers" for each of the weekly modules that changed based on the tokens earned. It would not change until the required tokens for that module were completed, regardless of the number of

non-required tokens that were completed. After the required ones were completed, all the optional tokens would then help students progress through their set of "stickers" until they had completed all tokens for that module. Students were consistently given qualitative feedback in addition to the visual marks serving as cues to progress in the token sheet through the learning management system. An example of a token tracking sheet can be found in Appendix 2. If a token was not adequately completed, students were given guiding prompts (*helpful feedback*) on anything that needed to be redone to earn the token. For Describe and Define sheets, they could re-do and resubmit. For Quizzes, they could submit a reflection and redo for each problem that they missed. They could do multiple iterations of this, including submitting questions for video notes, until sufficient display of understanding was achieved (*reassessment without penalty)*.

Program Context

These courses are both offered for Iron Range Engineering, an ABET-accredited general engineering program that offers junior and senior level courses and recruits from community college pre-engineering programs. It should be noted that Iron Range Engineering places high importance on implementing evidence-based practices, so many of the other courses in the program use other alternative grading practices, including the use of a 5-point grading scale [3]. Because the participants had experienced both community college courses with more traditional grading and other Iron Range Engineering courses using other alternative grading methods, the interviewer was able to ask follow-up questions about what benefits and challenges were specific to the SBG system, and which were more general to other courses that used other forms of alternative grading.

Interview Process

One of the researchers conducted 8 semi-structured interviews (attached interview protocol in Appendix 3) audio recorded and transcribed through Zoom, ranging from 15 minutes to 60 minutes (average 40 minutes). All students that completed Circuits and Fluids were invited to participate, and three students from Fluids and two students from Circuits participated in the study. Student participants selected their own pseudonyms; Damon and Sheryl were the students in Fluids, and Jessica, Adam, and Tim were the students in Circuits. Fluids had one instructor interviewed, and Circuits had two instructors interviewed. The interviewer was not the instructor for Fluids or Circuits for any of these students, and led the interviews with the protocol designed by the research team, asking follow up questions as needed. The protocol was designed based on existing literature in standards based grading to ask students about overall experiences with the grading system, and probe for potential impacts perceived by both the instructors and students. The order of the questions was chosen to allow students to frame their own experience in the context of benefits and challenges with the grading scheme, and then follow-up questions were asked about more specific perceived benefits and challenges discussed in other standards-based grading literature.

Analysis Process

Each of the researchers read through the transcripts, taking notes about emerging themes related to student gain and barriers. When this process was completed, these themes were then compared to the themes that were identified in [3] about perceived student gains and barriers. The analysis in [3] divided their faculty population into five different groups dependent on their level of experience with SBG. Our analysis specifically focused on the themes identified in responses from faculty with more than two years of experience implementing SBG. Lee et al. present eight gains and eight barriers that emerged when analyzing the survey responses of these faculty. Only two of the eight barriers were focused on student experience (others were focused on faculty implementation), so only those two were included in our analysis.

Transcripts were then analyzed to answer the following research questions:

1) Did the participants in our study discuss each of the gains and barriers identified in [3] in the context of their own experience? If so, how?
2) Which of these gains and barriers were specific to SBG courses, and which were more general to other courses using alternative grading?
3) Were there any additional gains or barriers that were discussed that were not included in [3]?

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Results & Discussion

In addition to the eight gains and two student barriers identified in [Lee], three additional gains and one additional barrier were identified. These gains and barriers are listed below with a further discussion with relevant quotes and meaning.

Gain 1. Recognize intended course objectives throughout the course

This theme was identified as a clear benefit by each of the instructors, indicated by being able to communicate the objectives of the course through certain deliverables being required versus not required. However, it was not explicitly stated by students. When asked how they decided what to cover, Adam responded, “Like the engineering principles?”, and Damon responded, “Do you mean the fundamental principles?” Sheryl and Jessica also refer to the fundamental principles throughout the interview. This reference to the fundamental principles points to students recognizing the course objectives, but they themselves do not identify this as a benefit. This could also be attributed to the fact that all classes taught in the Iron Range Engineering program use the concept of “fundamental principles”, so identifying intended course objectives is not just a feature of the SBG courses. Therefore, we conclude that there is some evidence to support that students recognize intended course objectives, but that this does not necessarily differ from other alternative grading strategies.

Gain 2. Opportunities for self-evaluate/assess

During the interviews, multiple students mentioned self-assessment practices. Tim noted that he would attempt and reattempt problems to support his learning: “I write down what I know and

approach the problem. A lot of times I get them right, sometimes I don't. When I don't, I go back to my notes and see what I missed, and that eventually supplements my knowledge." However, when asked how this compares to other classes, he said that he treated other classes the same: "So it was the same process, I would say, for all of them. Yeah, nothing really different." Sheryl also noted that the grading system helped "identify your strengths and weaknesses." When asked about how the grading system impacted her learning, she noted that the binary grading system helped her know what to go back to and improve: "Yes, I would say it impacted my learning because especially during exam period, when I'm reviewing […] my work, I use like my assignments and describe sheets to prepare for exams. It helped me know the ones that I needed to work on." On the other hand, some students framed resubmission as something they just "had to do." From the interviews, it was unclear to what level the implementation of SBG was impacting students' self-evaluation and self-assessment strategies, but some did at least acknowledge the instructor's evaluation and assessment of their work and use that to make decisions about their learning process. Therefore, we conclude that there is some evidence to support that SBG can support self-evaluation and assessment, but this should be further explored to determine to what extent students are practicing self-evaluation and assessment versus just completing what was required.

Gain 3. Focus on learning rather than grades

One of the most frequently discussed benefits in conversation with both students and instructors was the focus on learning and understanding over grades. All three instructors identified this gain as a primary motivation for implementing SBG, and four of five interviewed students listed it as a benefit. Damon, a Fluids student, explained that this grading structure influenced his motivation in the class: "I was not worried about – '[...]my grades are low, I need a high grade.' It's just more about. 'Oh, I need to understand this.'" This led to a recognition of the token spreadsheet as not just an assignment tracker but as a monitor of their mastery of the course material. According to Jessica, "I would take it as, if I didn't finish this token, it's because I didn't understand." Language used throughout the interviews reinforced the students' focus on concept mastery and application over an interest in receiving a particular grade on their assignments. One interesting differentiator that one student made between their experience in the course using SBG compared to other alternative grading systems was removing the idea of earning points. They started by talking about their experience in the program broadly where things are graded on a 5-point scale: "It first started with coming into the program when they told us that. 'Oh, we wouldn't need to focus on our grades.' That was kind of 'ehh' because of, I mean, it was still a grading system which was 1 to 5." They went on to compare that to Fluids: "But then in Fluids […] our grades are shown, but, like you can't know your full grade until the end of the semester. [The final grade] was kind of irrelevant in some sense […] So that kind of also shifted my mindset into just oh, focusing on the learning part, not worrying about the grades." The interviews showed that there is ample evidence of focusing more on learning than on grades in

alternative grading strategies, and that SBG can place even more focus on learning by removing scores on individual assignments.

Gain 4. Improve study and learning habits

Circuits Instructor 2 reflected that some of the habits students were building still seemed tied to the extrinsic motivation of earning the token rather than the learning, but that it still created structure for productive learning and reflection. They noted, "Reducing the stigma of not earning the token when it's due, I think can create space for people to identify practices that work for them to go back and learn what they needed." Damon reaffirmed this through his own reflection about being motivated by the tokens, but ultimately identifying better habits: "In the token system, you're more studying and you're studying every day, just so you can get the additional token that will make you meet at least the pass mark." Similarly, Sheryl noted that she practiced more reflection at the encouragement of her instructor: "You could also go there in person, like I don't understand what was wrong, and then she would explain it to you. But that's not it. She would also want you to go back and write that reflection." Therefore, there was some evidence to suggest that students improved their study and learning habits, but it is unclear if students are making habit changes or just practicing good habits in order to earn the grade they are shooting for. More work should be done to better understand if and how SBG can impact study and learning habits, especially beyond the completion of the course.

Gain 5. Fail early to address weaknesses and succeed later

All three instructors discussed the opportunity for students to redo failed assignments as a major motivator for implementing SBG in their courses. Circuits Instructor 2 said, "Sometimes you just like fail a quiz, and you throw it away, and you don't go back and learn it, right? So hopefully creating a space where everybody feels some level of accountability to go back and like, learn the material and feel comfortable engaging in that process." Circuits Instructor 1 noted the same benefit compared to other teaching experience in courses with traditional grading: 'Yeah, as opposed to in other classes where I've helped out with sometimes people [...] perform poorly on an exam or something like that, and just kind of like, move on from it. And just say, 'you know, I guess I just don't understand that subject.' But this way students really did like try and try again until they were able to get that passing score." Fluids Instructor had used a non-SBG approach to teach the same class three times before and noticed a difference in student engagement with past material: "I think they're redoing processes and asking questions earlier. They were hopefully able to succeed better there as well." This benefit was reflected in a few student interviews, and students framed failure to earn a token on a first attempt as a growth opportunity. Damon found this reassuring: "I knew that even if I failed it, I was not afraid to fail because I know that at the end of the day, as long as I redo the work and still get it, a token will be granted. [...] The work made me solve the problem all over again, and allowed me to understand the problem better." Sheryl used the instructor's feedback on *why* a token was not earned after an assignment attempt to target their studying: "And also for, like, define and describe sheets, if, like certain sentences

aren't worded right, you're not granted that token. And that's how the grading system works, so you'll go back and then actually find your mistake." The students contrasted this with a traditional grading approach. As Damon described, "Like [in] your traditional [course] [...] there's only like 2 major exams [...] in the semester, so like if I write an exam and I fail the exam. That is the end."

Gain 6. Self-regulated learning

Overall, SBG also helped students self-regulate their learning through scaffolding prioritization. Adam noted that "I can calculate how much […] work I want to put in […] and check in with our professors to see if I want to move past that letter, grade or state of where I'm at, and so I know exactly what the amount of assignments is required for me to do or ask for me to do, and what I would like to do." Similarly, Tim notes that it helped him know where they were at and balance that with other classes: "It definitively tells me where I need improvements and where I am doing well, and having a goal sets me on the right track. And I think that that was really important for my learning, because while learning circuits, I had other classes to worry about." Similar to the study practices, more work should be done to assess how SBG impacts a student's ability to self-regulate their learning beyond the one course, but overall, SBG shows promise in helping students create goals and balance them.

Gain 7. Transparent grading system

All of the students interviewed described the ease of tracking their course progress and corresponding grade using the token tracking spreadsheets. Multiple students contrasted this with prior classes where they felt uncertain about their standing in the class. As Adam said, " I just enjoy seeing exactly where I stand, and it's not as complicated as trying to calculate your own grade on a traditional like structure." Jessica, Adam, and Tim all described how this could help them achieve a particular letter grade for their transcripts. As Tim stated, "[The token tracking sheet] gives me a standard to which I could look at my grade and see how well I'm performing at every given time." Fluids Instructor shared that it was helpful to have a transparent and accessible grading system to aid in organization for both students and instructors: "And in helping me organize my class, stay on top of grading because students are seeing that progress as well on their end, I think for both of us we're able to track things better and stay on top of things." Timely feedback was necessary for students to know their standing (as is true in most grading systems). The simple accounting of token tallying made accessible to students in a visual format aided in the transparency of the grading system as a whole. This led to reduced student anxiety, as described in more detail below (Additional Gain 1: Peace of Mind). Overall, there was evidence in the interviews to support that SBG supported a more transparent grading system, and that students found this valuable.

Gain 8. Better understanding of performance management system used in industry due to its similarity to SBG

This Gain was not identified by either instructors or students in this study. To explore the impact of SBG on this Gain further, more direct questions could be asked about alignment between SBG and industry performance management.

Additional Gain 1. Peace of Mind

One Gain that emerged from the student interviews that was not included in the initial coding in [3] was the overall peace of mind that SBG brought to the students. Although this theme is tied in with transparency, previous findings focused more on the benefit of aligning the grade with learning. This finding focuses on the affective benefits of clear expectations and grading. Adam noted, "This is an ease of mind like a peace of mind, where I can see exactly where I stand, which is great." Tim noted that "Midway through the semester [...] I might be panicking like you know. 'What's, what's my grade,' you know all that, but then I check, and I see I'm doing well, and it, it gives me comfort." Damon reflected: "If we miss this stuff we can always read it again, and she's here to help us. […] That just removed the whole stress from focusing on your final grade." These comments suggest that, although there were still high expectations, those expectations were clearly communicated and still felt attainable.

Additional Gain 2. Quality of Feedback

Another Gain that was identified during the interviews was the quality and type of feedback that students received. Students acknowledged the value of both positive and constructive feedback. Damon compares his experience in the SBG course to some of the more traditional classes he's taken: "The feedback was always great. She, like, if you did something right she always said 'Oh, you did a nice job. You did a great job'. Then, if something was off or wrong somewhere, then she would elaborate and point out specific places you need to focus on, or you need to look at again […] She was always communicative about it […] Outside of IRE you don't get […] you don't get feedback that much. And I think that's something that I think a lot of students will actually like. So that you know what is wrong and where you can improve." Similarly, Tim reflects: "I got really good feedback […] they were very responsive and detailed in their explanation […] they were very, very accessible […] when maybe I, I get a problem wrong in quizzes and all they will let me know. 'Hey, you know, this is, this is what you got wrong.' And if I get things right? Same thing. 'Congratulations. You did good!' And that's really encouraging sometimes, you know. " Furthermore, Sheryl pointed out how this type of feedback was different from some of the other courses they were taking that used other forms of alternative grading: "What I just realized is most of the feedback from other courses weren't really on what wasn't good. It was mainly scores. And 'oh, great job! You know you did well in this part.' This focus on specific, constructive feedback was a way that SBG could be differentiated from other alternative grading practices.

Additional Gain 3. Encouragement through Earning Your Grade (Additive nature)
Students also noted the benefit of having an additive nature to the grade. Rather than "losing points", they're "earning their grade" through tokens. Damon noted that "The more you do, the more work you do the higher your grade is. which to me was a good system." Jessica was encouraged by the grading system: "[Tokens] also, like, gave more encouragement. Because it's like, it's like a token reward, as in you earn more instead of your losing points." This was another key difference between the use of SBG and the 5-point grading scale used by other instructors in the program – the additive nature of SBG was encouraging to students.

Barrier 1. Student pushback to change
Most students had not taken courses that used SBG before, so some onboarding time and preparation were necessary. Although students expressed some confusion in the first few weeks of the semester, they adapted quickly and did not report this to be a major barrier to their long-term success in their courses. To improve acceptance, Fluids Instructor noted the importance of planning and preparation: "I think with the way I set it up visually, I had to have the course all planned out from the beginning. So I think that's one of the things from the logistics side of thinking through things and really understanding, because I've got to have decided what are the essential tokens up front. What am I expecting students to do? What number of tokens is going to be equivalent?" This challenge is consistent with a perceived faculty barrier identified in [3]: Increased initial faculty workload. Although participants recognized potential for pushback, our interviews provide evidence that this can be overcome.

Barrier 2. Students' acceptance and understanding of SBG
Similar to Barrier 1, there was also some onboarding time to be able to understand how the grading system worked. Jessica shared, "At first just understanding what that token system was was a little confusing. It was a little challenging, but once you understood it, that became pretty easy, and it only took about, like, a week of the class." Adam reported that it took longer to become comfortable with the system, and as such he did not develop a habit of checking the token tracking spreadsheet until later in the course: "It's something that I hadn't seen before, and I didn't really check it in [the first seven weeks] until we were going into our [midterm check-in]." At the time of our interview, they felt comfortable with the tool and found it useful: "Having a token sheet that I could visibly see over time, helped me stay motivated, and know exactly where I stood." Overall, students' acceptance and understanding of SBG was perceived as a challenge, but one that was overcome relatively quickly.

Additional Barrier 1. Falling behind
An additional barrier identified by the faculty and student interviews that was not mentioned in [3] was the challenges related to falling behind because of the added flexibility. Circuits Instructor 1 noted that "Because students had the opportunity to continue to work with those subjects that they were having more difficulty with and not just write it off as something that

they weren't gonna get and like move on, that meant that some people ended up pretty far behind, because they would end up like taking that extra time to work on last week's material that they were still struggling with and then get more behind." Damon also mentioned that "It can be time consuming when you don't understand something because you would need to always go back to each to do." Sheryl noted that "If you miss, like, an assignment, it kind of complicates the rest of the process, because the learning for each module kind of, they're kind of related." While being able to redo things may be more specific to SBG, falling behind is a general struggle in any work that is time constrained (e.g., a semester).

Takeaways & Future Work

To summarize the coverage of all the gains and barriers by students and faculty, Table 1 presents which gains and barriers were discussed by each interview participant. As can be seen from the summary, the benefits were focused on much more than the challenges for both students and instructors for the way SBG was implemented in the Circuits and Fluid Mechanics courses at Iron Range Engineering. Seven out of the eight gains were mentioned by most interviewees. It is encouraging that so few barriers and challenges were mentioned with these grading schemes, which may somewhat be due to the format of the interview, but also speaks to the strength of this alternative grading method. There may have been some self-selection bias into the interviews by students who were optimistic about token grading since interviews were conducted on a voluntary basis, but with proper framing of these token grading methods, likely these barriers could be overcome since B1 was only mentioned by an one instructor, B2 is an instructor shift in explaining/showing the grading methodology, and AB1 is a common problem faced regardless of the grading method utilized.

	G1	G2	G3	G4	G5	G6	G7	G8	AG1	AG2	AG3	B1	B2	AB1
Damon -Fluids	■		■	■	■	■	■		■	■				
Sheryl - Fluids	■	■	■		■	■	■			■	■			■
Jessica - Circuits	■						■				■		■	
Adam - Circuits	■	■	■	■	■	■	■		■	■			■	
Tim - Circuits	■	■	■	■	■	■	■		■	■	■			
Instructor 1 - Fluids	■	■	■	■	■	■	■			■				■
Instructor 1 - Circuits	■		■	■	■	■				■				■
Instructor 2 - Circuits	■	■	■	■	■	■	■		■	■	■	■		■

Table 1. Summary table of gains and barriers that students and faculty mentioned in their interviews. A filled in square indicates they discussed the theme, a blank square indicates they did not.

For instructors, the research team feels there are three main takeaways from these findings that are implementable, inside and outside of SBG, with intentional effort:

1) Focus on **constructive feedback.** Regardless of whether a token, numeric score, check mark, etc. is being applied as feedback, providing students the positive affirmation of "great work!" or a correction of "spend some more time thinking about how you would further expand this idea", students find it valuable to know where they stand - what went well, what worked, what did not work - and a gentle nudge of how to improve, not just giving out answers. In this study, SBG lent well to this point because the focus was on students getting baseline understanding, which may have included redoing a token, requiring an explanation of whether or not that understanding was shown without misconception.
2) Be **transparent and communicative in grading schemes.** In conjunction with the point above, students want to know where they stand. This calls for the need of framing the way and frequency by which grading will occur, what the expectations for adequate-level-of-understanding are, and where/how students can track their progress within the course. While this study examined courses that had an individual tracking sheet for each student that was managed by a master spreadsheet, taking the time to understand and utilize the tools within any learning management system, and being timely in doing so, will help students understand their progress.
3) **Focus on standards and how those are adding to students' understanding.** Instead of consistently docking students for mistakes and focusing on the grade going down, focus on how students are meeting learning goals and progressing through the course to an adequate level of understanding.

In the future, the research team would like to further explore the nature of self-regulated learning and self-evaluation within SBG. Many students alluded to both being able to self-assess and self-regulate because of SBG, but this was not explored in depth. Iron Range Engineering is also well suited to be able to capture connections between SBG and performance management systems in industry since nearly all students are in full-time engineering positions throughout their undergraduate education. This did not come up in student responses in this study because of the interview protocol but also because the students are not yet in industry positions. A larger population of students from varying years in the program will be included in future studies to further explore the contrast and implications of the switch to SBG from other modes of grading.

Conclusion

While it may take some upfront work and planning, "Changing grading practices is considered the most expedient way to improve student achievement because of its significant role in facilitating learning and teaching" [3]. Many times, curricula can stay largely the same with just some reframing of how information, deliverables, and standards are presented to the students and assessed. This study, while limited in the number of participants, shows a strong, positive case for the value of applying SBG practices.

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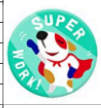
Appendix 1. Example Token Tracking Sheet Excerpt from Circuits

Fundamental Principle Tokens			
1. Electrical properties - DC	☑	Define/Describe	
	☑	Analyze/Apply	
2. Effective Resistance - DC	☑	Define/Describe	
	☑	Analyze/Apply	
3. Ohm's Law - DC	☑	Define/Describe	
	☑	Analyze/Apply	
4. Power - DC	☑	Define/Describe	
	☑	Analyze/Apply	
5. Kirchhoff's Voltage Law - DC	☑	Define/Describe	
	☑	Analyze/Apply	
6. Kirchhoff's Current Law - DC	☑	Define/Describe	
	☑	Analyze/Apply	
7. Node Voltage Method - DC	☑	Define/Describe	
	☑	Analyze/Apply	
8. Mesh Current Method -DC	☑	Define/Describe	
	☑	Analyze/Apply	
9. Voltage Divider - DC	☑	Define/Describe	
	☑	Analyze/Apply	
10. Current Divider - DC	☑	Define/Describe	
	☑	Analyze/Apply	
11. Norton/Thevenin Equivalents - DC	☑	Define/Describe	
	☑	Analyze/Apply	
12. Superposition - DC	☑	Define/Describe	
	☑	Analyze/Apply	

Professionalism Tokens			
Video Notes (completed w/ at least 2 questions and appropriate level of detail in format of your choice)	☑	Week 1	
	☑	Week 2	
	☑	Week 3	
	☑	Week 4	
	☑	Week 5	
	☑	Week 6	
	☑	Week 7	
Class Engagement (attend LCs and participate or make other arrangements with me)	☑	Week 1	
	☑	Week 2	
	☑	Week 3	
	☑	Week 4	
	☑	Week 5	
	☑	Week 6	
	☑	Week 7	
Timeliness (all assignments from the week turned in on time or other arrangements made)	☑	Week 1	
	☑	Week 2	
	☑	Week 3	
	☑	Week 4	
	☐	Week 5	
	☑	Week 6	
	☐	Week 7	

Fundamental Principle Tokens			
13. Electrical properties - AC	☑	Define/Describe	
	☑	Analyze/Apply	
14. Effective Resistance (Impedance) - AC	☑	Define/Describe	
	☑	Analyze/Apply	
15. Ohm's Law - AC	☑	Define/Describe	
	☑	Analyze/Apply	
16. Power - AC	☑	Define/Describe	
	☑	Analyze/Apply	
17. Kirchhoff's Voltage Law - AC	☑	Analyze/Apply	
18. Kirchhoff's Current Law - AC	☑	Analyze/Apply	
19. Node Voltage Method - AC	☑	Analyze/Apply	
20. Mesh Current Method - AC	☑	Analyze/Apply	
21. Voltage Divider - AC	☑	Analyze/Apply	
22. Current Divider - AC	☑	Analyze/Apply	
23. Norton/Thevenin Equivalents - AC	☑	Analyze/Apply	
24. Superposition - AC	☑	Analyze/Apply	

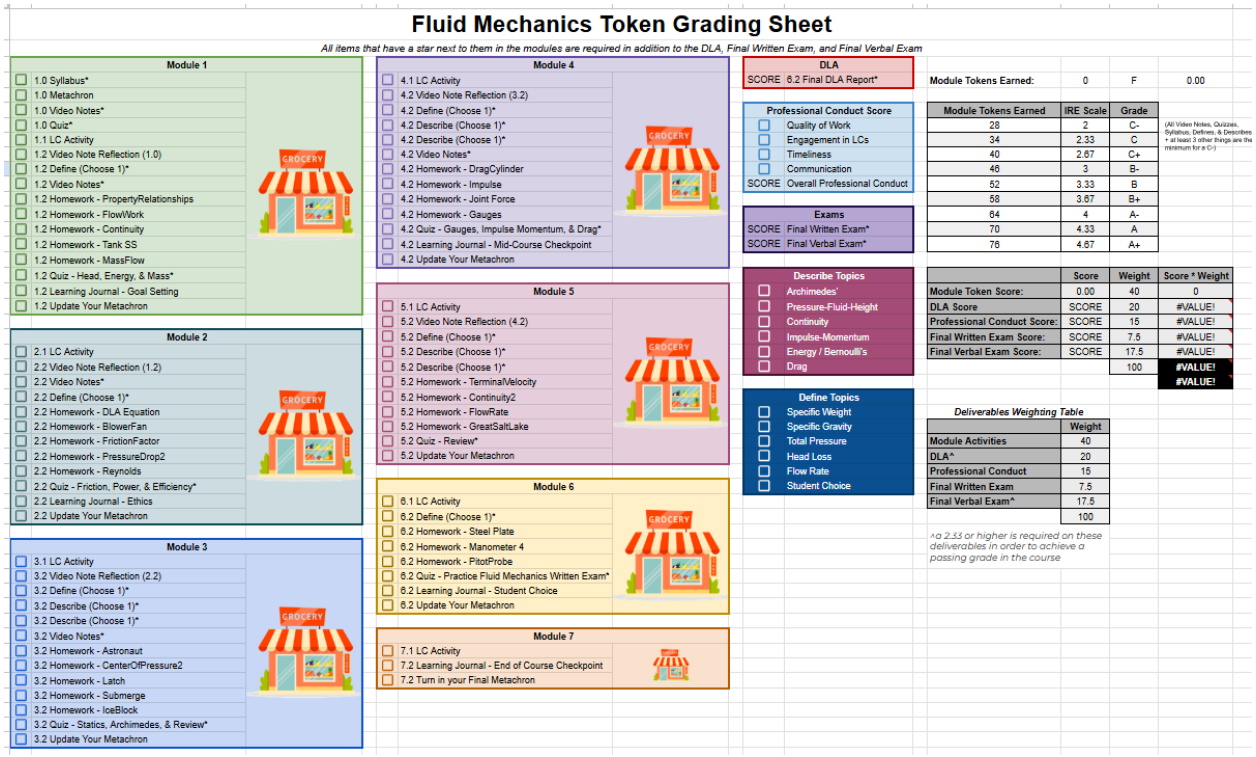
Professionalism Tokens			
Video Notes (completed w/ appropriate level of detail in format of your choice)	☑	Week 1	
	☑	Week 2	
	☑	Week 3	
	☑	Week 4	
	☑	Week 5	
	☑	Week 6	
	☐	Week 7	
Learning Journals (completed w/ appropriate level of detail)	☑	Week 1	
	☑	Week 2	
	☑	Week 3	
	☑	Week 4	
	☑	Week 5	
	☑	Week 6	
	☑	Week 7	
Timeliness (all assignments from the week turned in on time or other arrangements made)	☐	Week 1	
	☐	Week 2	
	☐	Week 3	
	☐	Week 4	
	☐	Week 5	
	☐	Week 6	
	☐	Week 7	

CYOA Tokens			
FE Exam Prep (1 token per problem set; up to 4)	☐	Problem Set 1	
	☐	Problem Set 2	
	☐	Problem Set 3	
	☐	Problem Set 4	
Deep Learning Activities (DLA) (2 tokens per DLA; up to 2 DLAs for 4 total tokens)	☑	DLA Proposal 1	
	☑	DLA Report 1	
	☐	DLA Proposal 2	
	☐	DLA Report 2	
Challenge Problems (1 token per problem set; up to 4)	☐	Problem Set 1	
	☐	Problem Set 2	
	☐	Problem Set 3	
	☐	Problem Set 4	

	FP Tokens Earned:	24
	Professionalism Tokens Earned:	4.57
+	CYOA Tokens Earned:	2
	Total Tokens Earned:	30.57

Tokens Earned	Grade
24	C-
26	C
28	C+
30	B-
32	B
34	B+
36	A-
38	A
40	A+

Appendix 2. Example Token Tracking Sheet Excerpt from Fluids



Fluid Mechanics Token Grading Sheet

All items that have a star next to them in the modules are required in addition to the DLA, Final Written Exam, and Final Verbal Exam

Module 1

- 1.0 Syllabus*
- 1.0 Metachron
- 1.0 Video Notes*
- 1.0 Quiz*
- 1.1 LC Activity
- 1.2 Video Note Reflection (1.0)
- 1.2 Define (Choose 1)*
- 1.2 Video Notes*
- 1.2 Homework - PropertyRelationships
- 1.2 Homework - FlowWork
- 1.2 Homework - Continuity
- 1.2 Homework - Tank SS
- 1.2 Homework - MassFlow
- 1.2 Quiz - Head, Energy, & Mass*
- 1.2 Learning Journal - Goal Setting
- 1.2 Update Your Metachron

Module 2

- 2.1 LC Activity
- 2.2 Video Note Reflection (1.2)
- 2.2 Video Notes*
- 2.2 Define (Choose 1)*
- 2.2 Homework - DLA Equation
- 2.2 Homework - BlowerFan
- 2.2 Homework - FrictionFactor
- 2.2 Homework - PressureDrop2
- 2.2 Homework - Reynolds
- 2.2 Quiz - Friction, Power, & Efficiency*
- 2.2 Learning Journal - Ethics
- 2.2 Update Your Metachron

Module 3

- 3.1 LC Activity
- 3.2 Video Note Reflection (2.2)
- 3.2 Define (Choose 1)*
- 3.2 Describe (Choose 1)*
- 3.2 Describe (Choose 1)*
- 3.2 Video Notes*
- 3.2 Homework - Astronaut
- 3.2 Homework - CenterOfPressure2
- 3.2 Homework - Latch
- 3.2 Homework - Submerge
- 3.2 Homework - IceBlock
- 3.2 Quiz - Statics, Archimedes, & Review*
- 3.2 Update Your Metachron

Module 4

- 4.1 LC Activity
- 4.2 Video Note Reflection (3.2)
- 4.2 Define (Choose 1)*
- 4.2 Describe (Choose 1)*
- 4.2 Describe (Choose 1)*
- 4.2 Video Notes*
- 4.2 Homework - DragCylinder
- 4.2 Homework - Impulse
- 4.2 Homework - Joint Force
- 4.2 Homework - Gauges
- 4.2 Quiz - Gauges, Impulse Momentum, & Drag*
- 4.2 Learning Journal - Mid-Course Checkpoint
- 4.2 Update Your Metachron

Module 5

- 5.1 LC Activity
- 5.2 Video Note Reflection (4.2)
- 5.2 Define (Choose 1)*
- 5.2 Describe (Choose 1)*
- 5.2 Describe (Choose 1)*
- 5.2 Homework - TerminalVelocity
- 5.2 Homework - Continuity2
- 5.2 Homework - FlowRate
- 5.2 Homework - GreatSaltLake
- 5.2 Quiz - Review*
- 5.2 Update Your Metachron

Module 6

- 6.1 LC Activity
- 6.2 Define (Choose 1)*
- 6.2 Homework - Steel Plate
- 6.2 Homework - Manometer 4
- 6.2 Homework - PitotProbe
- 6.2 Quiz - Practice Fluid Mechanics Written Exam*
- 6.2 Learning Journal - Student Choice
- 6.2 Update Your Metachron

Module 7

- 7.1 LC Activity
- 7.2 Learning Journal - End of Course Checkpoint
- 7.2 Turn in your Final Metachron

DLA

- SCORE 6.2 Final DLA Report*

Professional Conduct Score

- Quality of Work
- Engagement in LCs
- Timeliness
- Communication
- SCORE Overall Professional Conduct

Exams

- SCORE Final Written Exam*
- SCORE Final Verbal Exam*

Describe Topics

- Archimedes'
- Pressure-Fluid-Height
- Continuity
- Impulse-Momentum
- Energy / Bernoulli's
- Drag

Define Topics

- Specific Weight
- Specific Gravity
- Total Pressure
- Head Loss
- Flow Rate
- Student Choice

Module Tokens Earned: 0 F 0.00

Module Tokens Earned	IRE Scale	Grade
28	2	C-
34	2.33	C
40	2.67	C+
46	3	B-
52	3.33	B
58	3.67	B+
64	4	A-
70	4.33	A
76	4.67	A+

(All Video Notes, Quizzes, Syllabus, Defines, & Describes + at least 3 other things are the minimum for a C-)

	Score	Weight	Score * Weight
Module Token Score:	0.00	40	0
DLA Score	SCORE	20	#VALUE!
Professional Conduct Score:	SCORE	15	#VALUE!
Final Written Exam Score:	SCORE	7.5	#VALUE!
Final Verbal Exam Score:	SCORE	17.5	#VALUE!
		100	#VALUE!
			#VALUE!

Deliverables Weighting Table

	Weight
Module Activities	40
DLA^	20
Professional Conduct	15
Final Written Exam	7.5
Final Verbal Exam^	17.5
	100

^a 2.33 or higher is required on these deliverables in order to achieve a passing grade in the course

Appendix 3. Interview Questions

Questions for Course Instructors:

1. What were your goals and motivations when designing this grading system?
2. Tell me about the grading system used in [course].
3. What benefits did this grading system provide?
4. What challenges did this grading system provide?
5. How do you see this grading system impacting student learning processes?
6. How do you see this grading system impacting student learning in general?
7. How did you give feedback to students in this course?
8. From your observations, how did students choose what material to complete and in what ways?

Questions for Students

1. Please describe your experiences in the [course].
2. Tell me about the grading system used in [course].
3. What benefits did this grading system provide?
4. What challenges did this grading system provide?
5. How did this grading system impact your learning in general?

Note for the Interviewer: The following questions are looking for responses that allow a comparison to benefits found from faculty: benefits such as more direct feedback to students, improving students' abilities to self-assess, and a greater focus on learning. How does this align with student experience?

6. How would you describe your learning process in the course?

   Potential Follow Up: How does that compare to other courses you've taken?

7. How would you describe the feedback you received in the course?

   Potential Follow Up: How did the feedback provided compare to previous experiences?

8. How did you choose what material to cover?

   Potential Follow Up: How does that compare to other courses you've taken?