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Inclusive Assessment and SDGs

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Session XXXX

Inclusive Assessment and SDGs

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Abstract

Graduates of engineering programs should demonstrate mastery of the seven student learning outcomes required for accreditation by ABET. As champions of student success, it is the task of the university or college to ensure that some level of competency toward each outcome is achieved. The United Nations describes 17 Sustainable Development Goals (SDGs), and this paper seeks to connect the use of inclusive assessment practices to evaluate student learning in engineering education to three of those goals, SDG 4 – Quality Education, SDG 5 – Gender Equality, and SDG 10 – Reduced Inequalities. In the context of SDG 4, education is the process of facilitating learning; quality education requires eliminating disparities, fostering tolerance, and providing enhanced opportunities for employment. In order to provide the highest quality education, move toward gender equality, and reduce inequalities among students, the goal of grading must be reconsidered. Sufficient evidence exists that traditional approaches to grading, which may be classified as normative or summative, aim to differentiate students by communicating performance relative to others rather than indicating actual achievement of the student learning outcomes for a course or program. These methods foster negative competition among students and promote conflict between faculty and students as partial credit and fairness become topics of argument. On the other hand, formative assessment approaches aim to develop talent, which is more likely to reduce barriers faced by female engineering students as well as those students in underrepresented groups in STEM fields. These methods encourage reflection, which enhances learning, and they increase the intrinsic motivation to learn, which teaches skills and creates enthusiasm for life-long learning. This is the goal of education. Engineering education reimagined to allow a cycle of try, fail, study, try again, and learn, based on a growth mindset, is progress toward providing true quality education. It also levels the playing field, increasing the possibility of success for women in engineering, and reducing barriers often encountered by students of color, indigenous heritage, and/or those from lower socio-economic backgrounds. Reducing disparities in engineering education in the U.S. ultimately contributes to eliminating disparities in education around the world. A review of literature is used to make the connection between formative assessment methods and the effect of their implementation on the success of women and underrepresented minority students in engineering education. This is then compared to the indicators given by the UN for each of the three stated SDGs.

Introduction

Objective: To evaluate the literature that promotes alternative assessment in engineering education and to connect implementation of those methods to progress toward achieving three of the United Nations Sustainable Development Goals (SDGs) (SDG 4, SDG 5, and SDG 10).

Based on lessons from *The Goal: A Process of Ongoing Improvement*,[1] it is important to first identify the goal of education and then to identify the best way(s) to reach that goal. Finally, this paper considers the impacts of improving methods to meet the goal. In their book *Investment in Learning*, Bowen and Fincher assert that three primary goals of education are 1) practical competence, 2) development of thinking skills, and 3) affective characteristics.[2] Howson describes learning gain as "the improvement in knowledge, skills, work-readiness and personal development made by students during their time spent in higher education" in *A Handbook for Teaching and Learning in Higher Education*.[3] Ultimately, the goals of higher education in engineering are to provide practical knowledge and skills relevant to specific engineering fields and to assist students in the development of higher-level thinking skills.

According to Stephen Covey, author of Seven Habits of Highly Effective People, "The main thing is to keep the main thing the main thing."[4] In engineering education, the main thing is for our graduates to become successful engineers. The faculty is obligated to support student success by requiring students to demonstrate competency of each of the seven learning outcomes (see Appendix A) specified by ABET,[5] part of the criteria for accreditation of engineering programs. According to their website, "At ABET, our approach, the standards we set and the quality we guarantee, inspires confidence in those who aim to build a better world — one that is safer, more efficient, more comfortable and more sustainable."[6] The quality of our assessment of ABET outcomes is a direct measure of quality education and supports sustainability, specifically the UN Sustainable Development Goals, 4, 5, and 10.[7]

Traditional Education and Assessment

Traditionally, higher education coursework has been delivered through lectures and grades have been assigned as a way of assessing achievement of coursework. There is abundant literature supporting what has been described as outcomes-based or competency-based education since the 1970's,[8–19] including research projects involving engineering courses.[20–26]

Indeed, there has been a shift in education in recent decades from an emphasis on teaching to an emphasis on learning. The most common teaching model is based on the idea that "teaching is telling" and usually uses an expository or transmission method where lecture is used to present material described by course objectives. While there is some variation on lecture methods, what is important here is that the required course material is given to students by the expert (professor, instructor, teacher). The focus is on whether the course objectives enumerated in the syllabus are covered. It was later recognized that it was important to determine whether students were actually learning the course material. The shift to concentrate on learning led to the development of methods of active engagement and experiential learning. Course objectives were reframed into measurable student learning outcomes. While the emphasis has shifted from teaching to learning and student learning outcomes are specifically written to be measurable, the way outcomes are assessed, and the determination of competency continues to be questionable.

Norm-based grading approaches are common and are often implemented when the purpose of grades is seen as talent selection. Often these methods are associated with a fixed mindset, which is the thought that student abilities are set with a portion of students destined to fail and only a few capable of succeeding at the highest levels. Outcomes-based grading methods are used when the goal of assessment is focused on talent development. These methods are based on specifying well-defined student learning outcomes that describe what students must be able to do at the conclusion of the course, indicating the belief in a growth mindset where all students are capable of learning and succeeding. Various methods may be included in this category such as mastery, competency-based, specifications, standards-based, alternative, inclusive, and ungrading. All these methods have been used in engineering education usually when there is a desired emphasis on learning.

The traditional A – F grading system is simply a 300-year-old ranking system, which compares students to each other, usually based on points accumulated, rather than evaluating student competency or achievement of learning outcomes.[27,28] This is further complicated by the belief that grades should follow a normal distribution. The Central Limit Theorem states that the average of a sufficiently large sample of independent measurements will approach a normal distribution (Gaussian). A normal distribution of grades on the A, B, C, D, F scale typically yields something like 2% A’s, 14% B’s, 68% C’s, 14% D’s, and 2% F’s, meaning only 16% of grades are A’s and B’s.[29] According to this statistical model, most grades will fall close to the mathematical mean, with 68% falling within one standard deviation above and below the mean. A small number over-achieve or under-achieve within two standard deviations above and below the mean, and only a very few grades will be 3 standard deviations away from the mean, i.e., very few A’s. The result leads to the assumption that some students will inevitably fail and very few students will be able to achieve at the highest level.[29,30]

In reality, grades are not normally distributed, and we shouldn’t expect them to be. If most students are learning the course material, grades should at least be left-skewed if we insist on fitting to a normal distribution, indicating that a majority of students have achieved the student learning outcomes to a minimum competency level, with a significant number achieving at the highest level. If that is not the case, then we as educators need to revise our methods to increase the level of student success.[29] Revisions might include changing how we teach, e.g., active learning approaches, or we might change the way we assess student competency, e.g., alternative assessment methods, or perhaps changes are made to both teaching methodology and assessment techniques. Furthermore, there is concern that assigning a normal distribution to grades may sabotage efforts to improve success rates of more diverse student populations by increasing social division among students leading to destructive impacts on learning and self-esteem.[31]

Adding to the confusion about grading as ranking is the ambiguity of A-F grading. If the minimum passing grade of C translates to 70% of the total, what does that mean? For example, if 10 student learning outcomes are being assessed, a student who earns a 70 might have reached 70% proficiency in all 10 outcomes or they might have achieved 100% proficiency in 7 outcomes and 0% on 3 outcomes or some other combination. This makes a minimum of 70% quite ambiguous. In addition, some points may have been added for attendance, participation, attempting work but not succeeding, and other “points” that may not reflect student achievement.[32]

As the main accrediting organization for engineering education in the United States, ABET requires the assessment of seven student learning outcomes (See Appendix A). Despite being stated simply, these outcomes are complicated and each one consists of multiple skills to measure. There is no agreement on best practices for assessing these outcomes, but traditional points-based grading is still quite popular. The literature indicates that many alternative assessment methods are successful and offer the opportunity to better represent the actual competency of students.[5,10,13,21,22,24,26,33–35]

Perhaps some of the strongest arguments for alternative methods of assessment are related to the negative effects of traditional grading methods.[36] Evidence suggests clear disparities in educational achievement, especially in STEM disciplines, between the well-represented students and those underrepresented in STEM such as women and students of color, collectively referred to as underrepresented minority (URM) students. Not only do these students often underperform compared to their majority counterparts, but they also often drop out, change majors, or otherwise fail to complete engineering or other STEM discipline programs of study.[37]

Assessment and Sustainable Development Goals

It has been recognized that institutions of higher education play an important role in meeting the sustainable development goals. Because sustainability is best understood through the 3-pillar model of economics, social, and environmental contributions, universities should take a broad and holistic approach the integrating sustainability into the curriculum.[38] Beyond this broad responsibility, higher education also impacts specific SDGs in various ways. Most notably SDG 4 Quality Education mentions higher education explicitly in Target 4.3: "by 2030, ensure equal access for all women and men to affordable and quality technical, vocational, and tertiary education, including university."[7]

There may also be concern about the negative effects experienced by students under normative grading systems in which exams, deadlines, and high-stakes assignments are connected to stress and anxiety causing general underperformance.[32] Normative approaches to assigning grades can also set students against each other as they compete for their place in the ranking and sets up an adversarial relationship with faculty as students plead for points and partial credit. Many students in fact learn to game the system, reinforcing the importance of getting the most points possible with the least effort.[10] This is contrary to the goal of education for students to learn and develop.[32]

This use of formative assessments relies on believing in and working to develop a growth mindset, the belief that human intelligence can be influenced and developed. Changing how work is assessed can limit effects of bias on the part of the professor, while empowering students to own their learning and take responsibility for their success.[37] .

First conceived at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012, seventeen sustainable development goals (SDGs) demonstrate a global commitment to the objective of meeting the urgent environmental, political and economic challenges facing the world. Using alternative assessment methods in engineering education will specifically address three of those goals, SDG 4, SDG 5, and SDG 10.

Sustainable Development Goal 4

SDG 4 Quality Education is the goal to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.[7]

Consider a list of the criteria of an "ideal" grading system according to Nilson:[32]

1. Upholds high academic standards
2. Reflects students' achievement of outcomes
3. Motivates students to learn AND to do excellent work
4. Discourages cheating
5. Minimizes student and faculty stress
6. Makes students feel responsible for their grades
7. Minimizes student-faculty conflict (e.g., grade protests)
8. Saves faculty time
9. Gives students feedback they use

This list represents the flaws in the traditional grading system and presents the opportunity to develop better ways of assessing student learning in ways that better support student success and ultimately contribute to global advances in sustainability.

The following target in SDG 4 is relevant:

> Target 4.5
>
> By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations.
>
> > 4.5.1: Parity indices (female/male, rural/urban, bottom/top wealth quintile and others such as disability status, indigenous peoples and conflict-affected, as data become available) for all education indicators on this list that can be disaggregated.

Assessment methods used in higher education also have the potential of contributing to the progress of SDG 5 – Gender Equality, and SDG 10 – Reduced Inequalities. As discussed above, high-stakes exams, grades used as a tool for ranking students, and assessment methods whose purpose is the selection of talent rather than talent development are barriers to success of underrepresented students in engineering.

Sustainable Development Goal 5

SDG 5 Gender Equality is the goal to achieve gender equality and empower all women and girls.[7]

It is widely accepted that sufficient data indicates that students of particular groups are underrepresented in STEM fields largely because they are unsuccessful in coursework not because they are uninterested or unwilling to attempt the classes.[39–41] Disparities have been found for low-income students compared to higher-income students, for women compared to men, and recognized underrepresented minority students compared to students who are proportionally represented.[42] High engagement approaches such as active-learning, and including frequent low risk assessment, have been shown to increase student learning and to have disproportionate effect on URM students and women.[42–44] In other words, these methods work to improve the achievement of all students but have been demonstrated to help URM and women more than other students.

Contributing to the improvement of success rates of women, URM, and students from low-socioeconomic backgrounds also contributes to the advancement of SDG 10.

Sustainable Development Goal 10

SDG 10 is the goal to reduce inequality within and among countries.[7]

It has been shown that significant disparities exist in level of success achieved by under-represented minority (URM) student compared to non-URM students, which has resulted in efforts to improve representation and success of women and other URM students in STEM fields, including engineering.[45,46] Some interventions that shown success include active participation in activities during class and low-risk assessment.[44,47]

As student populations on university campuses become increasingly diverse, education itself is challenged to enhance programs whose objective is to increase participation and success of URM students. While new programs have been developed focused on enhancing student success, adjustments to methods of assessment have been changing more slowly.[48]

In a case study, Morris, et al. found that processes and administration of assessment in higher education create significant barriers to the implementation of inclusive assessment methods.[49] The focus that traditional assessment places on mode of delivery presents barriers to learning for URM students. Results of the case study in Morris emphasize these barriers faced specifically by students with self-described alternative learning needs (ALN).[49] Another study recruited students from diverse backgrounds and found that these students reported facing significant challenges presented by ambiguous assessment. Solutions founded on inclusive assessment design as proposed in the literature were supported by the student perspective.[50]

The following target in SDG 10 is relevant:

> Target 10.1
>
> By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average.

Education has been connected to income growth[51] and reduction of income inequality,[52] which means that improvement in engineering education as described here will produce more people with higher income potential, thus making progress toward this target of SDG 10.

As a method to reduce barriers, alternative assessments such as ungrading are often seen as more equitable.[53] Students report the increased self-efficacy demonstrated when students feel empowered to affect their own grade.[54] This also explains the commonly used "inclusive assessment" terminology to describe many of these methods that essentially focus on student learning of specific outcomes.

Summary and Conclusions

This review emphasizes the importance of considering how student achievement is assessed. Active learning techniques and alternative assessment methods have been shown to improve outcomes for all students. Experiential learning comes in many forms and there are many options for implementing active engagement into courses. Similarly, assessment methods that focus on talent development and seek to assess achievement of course learning outcomes that eventually reflect achievement of accreditation criteria in the form of ABET specified student learning outcomes consist of many different techniques. This means that faculty have a wide range of options to improve student success in their classes.

Considering all stakeholders of engineering education, the shift from fixed mindset to growth mindset represents a positive change for all. While the focus of the literature has been on benefits to students, especially women and under-represented minority students in STEM, all stakeholders will benefit from improving classroom teaching and assessment of outcomes. Students not only see improved outcomes but they experience less stress and anxiety. Faculty benefit from reduced conflict with students, more clarity of expectations, and improved student success. Colleges and universities benefit from the increased success of their graduates allowing them to demonstrate continuous improvement in providing high quality education. Employers benefit by having a better prepared workforce that is more diverse and representative of the population. Ultimately, these improvements affect the world by advancement in achieving SDGs 4, 5, and 10. Advances in providing quality education, enhanced gender equality, and reducing inequalities within the United States and between the U.S. and other countries benefit global civilization and improve the sustainability of this precious planet.

Appendix A – ABET Student Learning Outcomes

ABET accreditation https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/

To be accredited by ABET, the program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

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