How to Measure the Innovativeness and Entrepreneurship Features of a Curriculum?

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***Abstract*—This Research-to-Practice, Work in Progress paper attempts to provide a quantitative method to measure the innovativeness and entrepreneurship feature of a curriculum through available assessment data. This paper builds on our previous works relating systems thinking and design methodology to innovation and entrepreneurship. In this work, we propose an approach based on using the ABET's assessment process to obtain a measure for the innovativeness and entrepreneurship of the curriculum. We have used the engineering innovator characteristics as the base for our calculation. The proposed scheme also reveals the usefulness of the combined student outcomes assessment data. Given the nature of the collected data, it cannot be used as a way of comparing with other programs, and it is only a self-assessment indicator.**

Keywords—Innovation, Entrepreneurship, Assessment, ABET.

I. Introduction

Promoting innovation and entrepreneurship are not new concepts in academia and have been embraced by large and small universities. Efforts and approaches regarding this issue have become part of many major universities' strategic plans. Entrepreneurship education is a well-defined process that is being taught in many universities. Entrepreneurship is promoted through several means that include dedicated centers, courses, academic minors, and activities and events.

Innovation is an integral part of human existence and history. Innovation has been recognized as an essential component of advancements and modernization. Compared to entrepreneurship, innovation is not a well-understood process. We still do not have a consensus about the nature of innovation and a clear answer to difficult questions such as is it hereditary or not, and if it can be learned/taught. Researchers are still trying to find out the associated characteristics and how to best promote innovation. Since innovation is one of the critical components of entrepreneurship, the majority of recent works in this area focus on the association between innovation and entrepreneurship. The basic idea is that by promoting entrepreneurship, you are also promoting innovation, which is a much easier task. Before presenting our approach, we will first review several published works, which describe different innovation models in general and engineering innovativeness. Identifying the characteristics that are associated with innovation, essential traits of engineering innovativeness, and corresponding skills and behavior will enable us to provide feedback to students and practitioners, which will allow us to inform them about the innovative skills they can improve upon, as well as characteristics that cannot be changed or easily changed. In Section III, we will present our proposed model, which maps the innovative characteristics [11] to the current ABET [12] student outcomes and calculates the innovativeness of a program using a suggested impact factor. The idea is to obtain a more objective measure of the program's innovativeness that can be used for future improvements. Due to the nature of the assessment data, the calculated number is a self-assessment program indicator and provides a measure of innovativeness achievement (IA) for students for the year that the ABET data were collected. To the best of our knowledge, this is the first time such an approach has been proposed. The paper concludes with a short discussion about the suggested model and future work in this area.

II. Innovation and Entrepreneurship

In our previous work [1], we categorized the work in this area into four groups. The first group covered general academic features and requirements; the second group covered specific characteristics associated with entrepreneurship; the third group covered entrepreneurship mindset; and the fourth group included the curriculum delivery as its focus. In this section, only a small sample from group two covering innovation as a critical component of entrepreneurship is presented. Next, we will present sample research works that have covered innovation and innovativeness characteristics as a gateway to our proposed approach. A more detailed review is provided in our previous work [2].

Arnold and Wade in [3] believe that entrepreneurship is a process of small incremental innovation as opposed to making a giant leap forward and sees an entrepreneur as being very focused, seeing what others have overlooked. Binder and Knauder in [4] provide a model for a theoretical conception of entrepreneurship studies for engineering students. They indicate that it is based on the following four modules: (i) personal development, (ii) from idea to innovation, (iii) public relations and media, and (iv) executing an idea – business plan. Pech et al. in [5] cover innovation, design, and entrepreneurship for engineering students. Based on the published works, they propose a collaborative and experiential course on innovation for engineering students. Lugo et al. in [6] present alignment of an engineering course in design thinking and a marketing

course, focused on consumer behavior as a way of promoting innovation and entrepreneurship.

Next, we will focus on works that can help us understand innovation, its associated characteristics, attributes better, and investigate its relationship with engineering design. Fisher et al. in [7], based on open-ended interviews with a diverse set of innovation experts, have presented a "mental model" to describe innovation and innovation education. A mental model captures a connected set of observations, assumptions, and beliefs about a domain-specific situation that people draw upon when they think of a problem. The authors have indicated that with some variations in specific words, the experts consistently named the same set of key concepts: something new that is implemented and provides value to describe innovation. They have also provided an example of attributes (personal attributes, skills, the process of innovation, and environment of innovation) of elements that act as promoters or inhibitors of innovation. The elements under the process of innovation included: systems understanding of the organization and related spheres and decision making with an understanding of the system. Purzer et al. in [8] have identified five critical characteristics of an engineering innovator: deep knowledge, active learner/curious, vision/caring, team manager/leader, and risk-taker. Menold et al. in [9] have examined innovativeness assessment and analyzed ten measures and models of innovativeness through two lenses: (i) their attributes vs. actions and (ii) their relationship to cognitive level, style, and effect. The authors concluded that a comprehensive, rigorously validated psychometric instrument does not yet exist to assess the aptitudes, skills, knowledge, personality traits, and behaviors that are indicative of an innovative engineer. Peterfreund et al. in [10] have examined the changes over 2012-2015 in Innovation and Entrepreneurship (I&E) initiatives within the National Center for Engineering Pathways for Innovation's community. The authors have indicated that in engineering, innovation is associated with design. They also reported a high level of agreement that I&E should be offered as part of the required curriculum. A more recent work [11] indicated that they had identified the most important characteristics of engineering innovators. The authors define the innovation process to have a beginning (discovery), a middle (development), and a completion phase (implementation). They also add that evidence does not connect claims on creating innovations or being more innovative to engineering student learning experiences and outcomes. This work challenges the authors' claim. They present their five-year study in a table (Table 1 in [11]) and identify twenty characteristics related to innovative behavior, capturing a significant number of innovation characteristics suggested in various papers. We have used this paper in our previous works, and it is the starting point for this work. We believe one way to understand innovation is to study innovativeness characteristics, and innovation can be promoted by fostering those characteristics. This is the approach that we suggested in our previous work [2019], but as we pointed out, more work needs to be done in this area. For example, for an inventor to be a "visionary" is more important or an "associated thinker?" Nevertheless, we believe [11] has identified many essential characteristics of innovation that are very useful.

III. PROPOSED APPROACH TO MEASURE INNOVATIVENESS AND ENTREPRENEURSHIP

Innovativeness characteristics only provide us with the components that make up innovation but not their required combination. The exact combination needed differs for each individual and rests on many factors such as background, environment, etc. Therefore, we can only talk about the mix in general terms, such as being “creative” has a higher impact than being a “developer” in becoming an innovator. The more we know about the “required” combination, the more efficient our promotion will become, and this is the key requirement in our proposed approach. Therefore, we are proposing a ranking version of Table 1 in [11]. The new columns in the table, given below, are based on general knowledge and experience. More data collection experiments are needed to fine-tune the assigned factors. We also believe being “creative” is a complex character that would make sense if removed from the table. Next, we will map the characteristics to the ABET Outcomes. Table 1 represents our initial work in this area; we intend to expand it further.

TABLE 1: INNOVATIVENESS MEASUREMENT - CHARACTERISTICS’ IMPACT FACTORS & ABET MAPPING

Characteristic	Impact Factor	Related ABET Student Outcomes
Alternatives Seeker	0.85	1, 2, 4
Analytical	0.75	1, 2, 6
Associative Thinker	0.80	1, 2, 4, 6
Challenger	0.65	2, 6
Collaborator	0.50	2, 3, 5
Communicator	0.20	2, 3, 5
Creative	1.00	1, 2, 4, 6
Curious	0.90	1, 6, 7
Developer	0.55	1, 2, 5, 6
Experimenter	0.45	2, 6
Implementer	0.40	5, 6
Knowledgeable	0.70	1, 2, 4, 6, 7
Market/Business Savvy	0.05	4, 6
Passionate	0.30	2, 4, 5
Persistent	0.60	1, 2, 6
Risk Taker	0.35	6
Self-Reliant	0.25	1, 6, 7
Leader	0.15	2, 5
User Empathetic	0.10	2, 4
Visionary	0.95	2, 4, 6

The innovativeness calculation will be based on using student outcomes’ evaluations calculated by applying the associated performance indicators (PIs). The reason behind using the assessment data is due to the availability of the information and,

therefore not requiring additional resources to start the process. We acknowledge that additional studies focusing on each innovativeness characteristics would benefit the proposed method, but it will also come with a price tag that most institutions cannot afford. We also emphasis that the (current) proposed evaluation using the available information provides additional insight into innovation and entrepreneurship that have not been explored before. To illustrate the process, we will start with an example, looking at "analytical" characteristic, which has the following assigned impact factor and student outcome associations.

TABLE 2: IMPACT FACTOR & ABET MAPPING FOR "ANALYTICAL" CHARACTERISTIC

Characteristic	Impact Factor	Related ABET Student Outcomes
Analytical	0.75	1, 2, 6

We will use the following proposed equations to find the measurements of interest.

$$Analytical \triangleq C_2 = f(O_1, O_2, O_6) \quad (1)$$

$$(IA)_{upper} = (IF)_i * Max(O_1(E[PIs]), O_2(E[PIs]), O_6(E[PIs])) \quad (2)$$

$$(IA)_{lower} = (IF)_i * Min(O_1(E[PIs]), O_2(E[PIs]), O_6(E[PIs])) \quad (3)$$

$$IM = \left(\sum_{year=1}^{year=3}(IA)_{year}\right)/3 \quad (4)$$

Where, C_i means the i^{th} entry in Table 1; O_i means calculation is related to ABET's Student Outcome i; O_i(E[PIs]) means the average of performance indicators that are defined for the i^{th} Outcome, $(IF)_i$ means impact factor related to the i^{th} entry in Table 1, $(IA)_{upper}$ means the maximum Innovation achievement, $(IA)_{lower}$ means the minimum Innovation achievement, and IM means Innovativeness measure.

Next, we will take a look at the performance indicators for the student outcome results. For illustrative purposes, let's assume that we have the following results for Outcomes 1, 2, and 6. The figures are part of a normal ABET assessment process that is generated and used for continuous improvement discussions. For example, figure 3 indicates that Outcome 6 has been assessed using three performance indicators with a set target of 80%. For this outcome, based on a set rubric, 73.3% of the students have demonstrated "exemplary/satisfactory" results for the first performance indicator. The explanation for the other figures is similar.

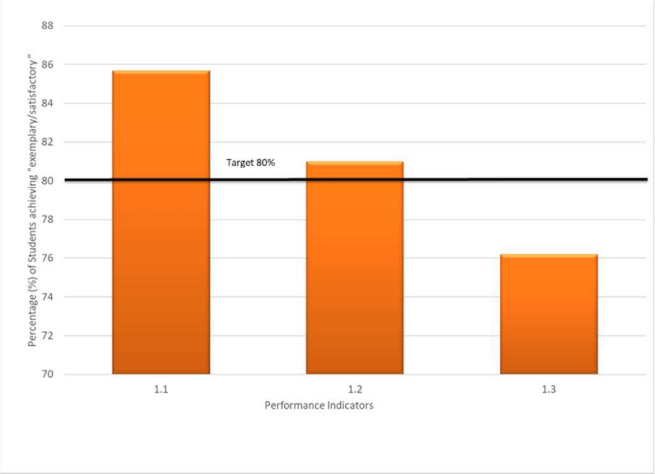

Fig. 1: Summary of student Outcome 1 (average = 81%)

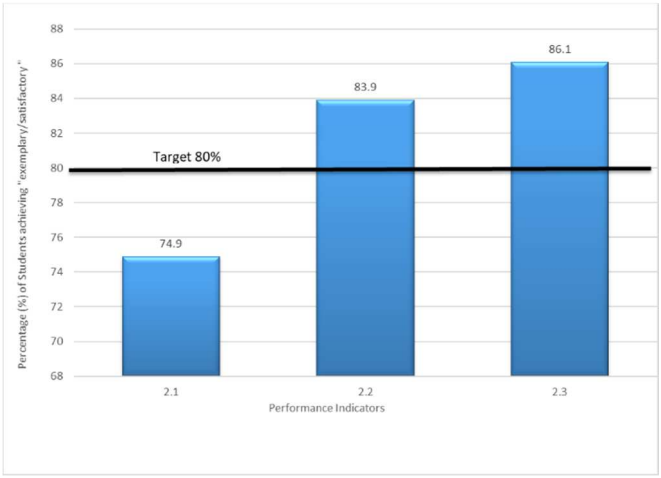

Fig. 2: Summary of student Outcome 2 (average = 82%)

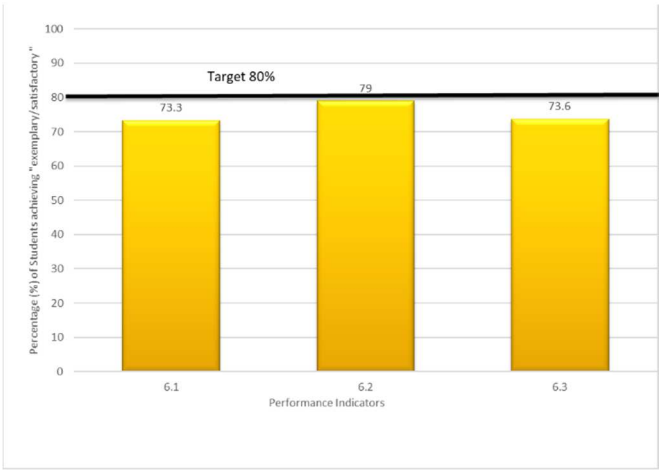

Fig. 3: Summary of student Outcome 6 (average = 75%)

Next, we will pick the maximum of the average numbers for the student achievement of the outcomes. For this example, we have the following averages: 81%, 82%, and 75%, which the maximum will be 82%. Next, we will multiply this number by the impact factor (0.82*0.75), which we get 0.615. By

repeating the same process for the other characteristics, we get an indicator of innovativeness achievement for students for the year that the ABET data were collected. The maximum IA for each year is 10.5, which is the sum of the impact factors. We define the innovativeness measure (IM) of the curriculum by averaging the IAs for three consecutive years, assuming no change in the curriculum or PIs ($IM = \left(\sum_{year=1}^{year=3}(IA)_{year}\right)/3.$)

If we repeat the same process but using the minimum of the average numbers, we will have a range for the IM. We suggest defining a target number for the IM. Since the data comes from the ABET assessment process, we can identify the courses that can increase the IM number to meet a higher target. By focusing on the maximum (minimum) PI as the base for IA calculation, we can identify the leading (lagging) contributor(s) to the innovativeness measure, and therefore provide a pathway for further curriculum enhancement.

For entrepreneurship measurement, we use the same process with a modified version of Table 1, which considers the characteristics that are more important in entrepreneurship. Table 3 shows a possible option.

TABLE 3: ENTREPRENEURSHIP MEASUREMENT - CHARACTERISTICS' IMPACT FACTORS & ABET MAPPING

Characteristic	Impact Factor	Related ABET Student Outcomes
Alternatives Seeker	0.70	1, 2, 4
Analytical	0.05	1, 2, 6
Associative Thinker	0.25	1, 2, 4, 6
Challenger	0.15	2, 6
Collaborator	0.75	2, 3, 5
Communicator	0.80	2, 3, 5
Creative	1.00	1, 2, 4, 6
Curious	0.30	1, 6, 7
Developer	0.20	1, 2, 5, 6
Experimenter	0.85	2, 6
Implementer	0.10	5, 6
Knowledgeable	0.70	1, 2, 4, 6, 7
Market/Business Savvy	0.95	4, 6
Passionate	0.45	2, 4, 5
Persistent	0.60	1, 2, 6
Risk Taker	0.50	6
Self-Reliant	0.40	1, 6, 7
Leader	0.35	2, 5
User Empathetic	0.55	2, 4
Visionary	0.9	2, 4, 6

IV. REMARKS AND CONCLUSION

In this work, we proposed an approach to measure the innovativeness and entrepreneurship of an engineering curriculum by using the ABET's criterion 3 assessment process and data from criterion 4. We have used the engineering innovator characteristics as the base for our calculation. This is preliminary work, and the equations to calculate IAs and IM are intentionally chosen to be linear and straightforward so that the focus be on the methodology. The calculation can be done with the available ABET assessment data. For example, in Table 1, Outcome two is identified in fifteen different characteristics, and therefore, PIs representing the data for this outcome is a combination of those characteristics. For simplicity, in this work, we have assumed that the innovative characteristics have an equal effect on each outcome. The different weights are considered for only the overall innovation calculation. This means, for example, the data for Outcome two can be used, without alternation, in calculations of the fifteen identified innovativeness characteristics. In future works, we intend to modify this assumption and assign/suggest different weightings of outcomes for calculating the IAs. We plan to continue this work and incorporate other research works related to the assignment of the impact factors and assessment associations in Tables 1 and 3.

The proposed scheme also reveals the usefulness of the student outcomes assessment data beyond the ABET accreditation requirement. Given the nature of the collected data, we should point out that the proposed calculation cannot be used to compare programs unless the programs have the same PIs and it is only a self-assessment indicator.

REFERENCES

[1] A. Azemi, "Benefits of Teaching Systems Thinking as part of an Engineering Curriculum," *Proc. of the 49th IEEE Frontiers in Education Conference (FIE),* Covington, KY, 2019.

[2] A. Azemi, "Promoting Innovation and Entrepreneurship as part of an Engineering Curriculum," *Proc. of the 48th IEEE Frontiers in Education Conference (FIE),* San Jose, CA, 2018.

[3] Boni, A., L.R. Weingart, and S.Evenson. "Innovation in an Academic Setting: Designing and Leading a Business Through Market- Focused, Interdisciplinary Teams," *Academy of Management Learning and Education,* Vol. 8, No. 3, pp. 407–417, 2009.

[4] Anid, N.M., M.A. Panero, and B. Carbonette, "Innovation and Entrepreneurship through Industry-Academic Collaborations: A Collegiate Model for Economic Development," *Proc. of the 123rd ASEE Annual Conference, New Orleans, LA, 2016.*

[5] Pech, R., B. Lin, C-K Cho, and H. Al-Muhairi, "Innovation, Design and Entrepreneurship For Engineering Students, Development and Integration of Innovation and Entrepreneurship Curriculum in an Engineering Degree," *Proc. IEEE Global Engineering Education Conference (EDUCON)*, pp. 389-396, 2016.

[6] Lugo, J.E., M.L. Sapata-Ramos, and M.J. Perez-Vargas, "Promotion of Innovation and Entrepreneurship in Engineering Design by Synchronizing Engineering and Business School Courses," *Proc. Of the ASME IDET/CIE Conference,* Charlotte, NC, 2016.

[7] Gerber, E., C. Martin, E. Kramer, J. Braunstein, and A.R. Carberry, "Developing an Innovation Self-Efficacy Survey," *Proc. of the 42nd IEEE Frontiers in Education Conference (FIE) ,* Seattle, WA, 2012.

[8] Fisher, E., M. A. Biviji, and I. Nair, "New Perspectives on the Teaching Innovation to Engineers and Exploration of Mental Models of Innovation Experts," *Proc. of the 118th ASEE Annual Conference, 2011.*

[9] Ferguson D.M., and M.W. Ohland. "What is Engineering Innovativeness?" *International Journal of Engineering Education*, Vol. 28, No.2, pp. 253, 2012.

[10] Purzer, S., K. Jablokow, D.M. Ferguson, M.W. Ohland, and J. Menold, "Collaborative research: Identifying and assessing key factors of engineering innovativeness," *Proc. of the 121st ASEE Annual Conference (NSF Grantees Poster Session*), Indianapolis, IN, 2014.

[11] Menold, J., K. Jablokow, S. Purzer, et al., "A Critical Review of Measures of Innovativeness," *Proc. of the 121st ASEE Annual Conference*, Indianapolis, IN, 2014.

[12] ABET. Criteria for accrediting engineering programs, 2020-2021. Retrieved 2020, www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/#program