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A Diversity Index to assess college engineering team performance

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Abstract

We have developed a Diversity Index (DI) to better quantify the impact of eight traditionally underrepresented demographic categories in chemical engineering (“Women,” “Non-Binary,” “Black or African American,” “Hispanic or Latino/a,” “Asian, American Indian or Alaska Native, Middle Eastern, or Native Hawaiian or other Pacific Islander” (Asian/other for a short version), “LGBQT,” “Disabilities,” and “First Generation”). We then compared the DI with a Minority Index (MI), which only reflects the ratio of “Non-White American male” members to the total number of members but exhibits poor representation for diversity when teams are conformed mainly by minority representatives. We obtained data by instructor observation (no surveys taken at this time) from 69 self-selected teams that performed 37 technical projects and 101 outreach projects in eight junior/senior chemical engineering courses. Results show that the DI is a promising quantitative tool to analyze and track diversity impact. For outlook, we hypothesize that a “diversity rewarded” option may incentivize students to self-select team members that bring increased diversity, promote inclusion, and yield statistically measurable improvement in performance.

Introduction

Peter M. Blau developed a “theory of how macrosocial structure influences microprocesses” (Haveman 1995). His central thesis is that “population structure, the composition of societies or societal subunits along salient dimensions of social position, governs individuals’ life chances by providing opportunities for and imposing constraints on interpersonal relations and social mobility” (Haveman 1995). Social integration becomes determined by the extent and intersections of social differentiations, which assume two major forms, inequality (if differences are hierarchical ordered, like authority and power) and heterogeneity (if differences are unranked, as religion or ethnicity) (Blau 1977). In addition, this social structure needs to be combined with individual characteristics to understand organizational performance (Haveman 1995). Moreover, mobility, or the processes leading individuals or groups to changes in social positions also influences social integration (Blau 1977).

The distribution of individuals in groups according to certain criteria for association provides the quantitative approach to analyze these influences. Structural parameters based on individuals’ attributes (i.e., age, race, education) define these criteria. The significance of an attribute to compose a parameter (i.e., the portion of individuals with such an attribute) on social relations for a specific society or organization requires empirical testing, even if the biological or psychological nature seems determinant (Blau 1977). Blau distinguished two types of parameters: nominal (unranked distinctive groups, i.e., sex, race, religion, ethnicity) and graduated (continuous ranked position within a group, i.e., age, income, education). In this way, group membership (a nominal parameter) and status (a graduated parameter) comprise all individual characteristics influencing social relations. They provide for the two basic forms of social differentiation: heterogeneity (nominal group) and inequality (graduated status) (Blau 1977).

Heterogeneity can be measured by “the distribution of a population among groups in terms of a nominal parameter” and calculated as an index (HI) by equation (1):

$$HI = 1 - \frac{\sum x_i^2}{(\sum x_i)^2} \qquad (1)$$

where x_i is the number of individuals in the i^{th} group, and the sum is taken over all the groups. The heterogeneity index starts at 0 if all the individuals belong to only one group (uniformity) and increases up to 1 as the number of groups with even numbers of members increases (i.e., if every individual is taken as a different singular group). This calculation reduces to equation (2) if groups are represented by the fraction of the total population (Blau 1977)

$$HI = 1 - \sum p_i^2 \qquad (2)$$

where p_i is the fraction of members in i^{th} group (the number of individuals in the group divided by the total population). This is commonly referred to as the Blau’s index - though it was first developed by Simpson in 1949 (Simpson 1949) – and it is the most used method in the scientific literature to measure diversity (Harrison and Klein 2007, Usher and Barak 2020).

Diversity continues to be a much debated and often confusing term, but it can be taken as “the distribution of differences among the members of a unit with respect to a common attribute” (Harrison and Klein 2007), equivalent to Blau’s heterogeneity except for the specific reference to a common attribute. To date, the relation between team diversity and performance has not shown conclusive results: diversity based on bio-demographics (i.e., gender, ethnicity, age) appears to show no positive effect, while diversity based on acquired functionalities (i.e., education, skills) seems to show positive impact on team performance (Usher and Barak 2020). Studies on the relation of team diversity and performance have also shown contradictory results (Usher and Barak 2020). In addition, the intersection of individual characteristics with the culture of a specific team also plays a significant role that can lead to different outcomes due to member behaviors (Trytten et al. 2015).

Diversity is currently sought as a necessary component of engineering education (Weber and Atadero 2021) required for the future workforce. In the words of William W. Wulf, then the president of the National Academy of Engineering, “without diversity we limit the set of life experiences that are applied, and as result we pay an opportunity cost – a cost in products not built, in designs not considered, in constraints not understood, and in process not invented” (Wulf 2001). After emphasizing his conviction that “engineering is a very creative profession”, he went on to say that “[at a] fundamental level, men, women, members of minority groups, and people with physical disabilities experience the world differently. Those differences in experience are the “gene pool” from which creativity springs” (Wulf 2001).

Methodology

Class description

We collected data by direct observation of the instructor in eight chemical engineering courses for the period of spring 2019 to fall 2021. One course is for junior students (Reactive process engineering) and two courses are capstone courses for senior students (System Engineering I: Dynamics and Modeling, and Systems Engineering II: Process Design). These are three out of the six "Pillar" courses that provide the backbone for the chemical engineering curriculum at the University of Pittsburgh (McCarthy and Parker 2011). They are all five credit courses each with six hours/week of lecturing and a two hours/week recitation. The first two courses are complemented with a co-requisite one-credit lab course, and the last with a two-credit safety and ethics course. The first and last courses run during the spring and summer terms. The second course runs only during the fall term. Student populations in the classes traditionally range from 24 (in summer classes) to 58 (during the fall and spring semesters).

These Pillar courses provide for extended instructor-students relationships with six to eight hours of contact time every week, in addition to office hours and wide availability for meetings and discussion. This provides a unique opportunity where the instructor can become well acquainted with individual students. In addition, some students will opt to take three courses with the same instructor, and this multiplies the number of opportunities for the instructor to get abundant and reliable information on the students. We used this direct approach (based on instructor's observation) to explore the initial proof-of-concept. A more systematic IRB survey-based approach will follow.

Extensive technical teamwork enriches these courses. The course on Reaction Engineering includes a technical project where students research a chemical product of their interest and a corresponding manufacturer and detail product characteristics, safety, historical development, production, kinetics simulation, uses, markets, business and impacts on welfare, health, society, culture, and environment. The course on Process Control includes a Global Project where students identify a problem in a country outside the US and collaborate with partners from that country in documenting, assessing, and providing potential solutions. The course on Process Design includes a Design Project for a midsize commercial styrene production plant with streams and units' specifications, and economic evaluations. In addition, each course includes an Outreach Project where students select a non-technical audience and deliver career-related content adapted to the audience. Most of the teams opt to make presentations or hands-on demonstrations at K-12 programs for the promotion of STEM careers.

Student visible characteristics and identities

In this first phase of the study (2019-21) we made no attempt to collect information by survey or requesting specific information from students to confirm characteristics of underrepresented identity affiliation (The only slight exception was asking one course about their first-generation identity). We considered eight characteristics of different demographics in the composition of the Diversity Index (DI). We made no attempt to support a rigid definition of these characteristics but an "ordinary understanding" approach that is certainly bias-conditioned. When students self-form groups, they do not have survey data to know which identities their classmates might use to describe themselves. Instructor obtained the data on visible student characteristics and identities by interpretation of physical characteristics, names, and comments from the students, as presented in Table 1, and this is expected to be similar in how students may interpret their classmate's identities in a classroom setting. We acknowledge that without collecting data directly from students themselves, the identities selected for the calculations will underrepresent the actual diversity of identities present in the student populations.

Table 1. Visible characteristics and identities used in index calculations

Characteristic	Symbol	Identifiers (by observations)
White American male	WAM	Skin color, name/last name.
Women	W	Body stereotype.
Non-binary	NB	Comments students make on supporting "sex as a social construct", or the use of identifying pronouns like "they".
Black or African American	AA	Skin color.
Hispanic or Latina/o	H	Name/last name, identification by student as having Hispanic heritage
Asian/Other	AO	Body stereotypes, names/last names, identification of student as of Asian/another ethnicity
LGBQT	LGBQT	Name change, use of identifying pronouns different from body stereotypes, direct/indirect identification.
Disabilities	D	Reported by the Disability Resources and Services Department at the university.
First generation	FG	This characteristic was incorporated recently in fall 2021 upon notice of the potential significance. This is the only demographic identified by confirmation of students. It is used to evaluate the impact on index calculations. Additional statistics from the Engineering School data Warehouse are used to estimate the representation of this characteristic, as reported below.

Minority index calculations

We used a Minority Index (MI) to approach the significance of diversity. The MI is defined by the ratio of non-WAM to the total population.

$$MI = 1 - \frac{WAM}{Total} \qquad (3)$$

The MI has the advantage of simple calculation and data gathering, it ranges between 0 and 1, and it provides a good standard for comparisons. It is therefore convenient to track in time with the evolution of under-represented groups, and it holds significant meaning for large groups with a dominant or significant composition of WAM as discussed later in the Results section. However, the MI is defective in representing diversity when approaching small groups with a reduced or non-WAP component (e.g., a group of four women will result in an MI=1, but such a group will reflect no diversity within that group). This limitation is further assessed by comparing it with the corresponding Blau's index (HI) in Table 2.

Table 2. Comparison of the minority index (MI) with the Blau's index (HI)

p	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
MI	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10	0.00
HI	0.00	0.18	0.32	0.42	0.48	0.50	0.48	0.42	0.32	0.18	0.00

where *p* is the proportion of WAM. Notice that Blau's index (HI) correctly assesses diversity (i.e., a group made only of WAM, p=1, gives a 0 value, while a group of non-WAM, p=0, gives also a 0 value) but it fails to provide an immediate representation of underrepresented groups (i.e., a group of only underrepresented members, p=0, yields a value of 0, the same as a group of no underrepresented representatives, p=1).

Diversity index calculations

We hypothesize the DI would provide more reliable information compared to the MI, particularly for small groups. This DI first identifies the dominant characteristic of the group and counts the other members as "diverse". A ratio of these "diverse" members to the total number of members in the group provides a first approach to calculate the DI (equation 4).

$$DI^{*} = 1 - \frac{Dominant\ characteristic}{Total} \qquad (4)$$

where the Dominant characteristic accounts for the number of individuals with the dominant characteristic and Total accounts for the number of individuals in the entire group.

An example provides for the significance and difference with the MI and HI as presented in Table 3.

Table 3. An example of preliminary comparison of MI, HI, and DI

Group	MI	HI	DI	Comments
1 WAM, 3 W	0.75	0.375	0.25	This group has a high MI as most of the members are women, but it is limited on diversity as only one member has a different main characteristic
3 WAM, 1 W	0.25	0.375	0.25	This group has a low MI as only one member is of an underrepresented group, and the diversity is also low due to this only difference
2 WAM, 2 W	0.50	0.50	0.50	In comparing with the two previous groups, it is noticeable that the HI weights more on one single difference while the DI offers a more "lineal" behavior

The DI takes one step further counting for multiple diversities (i.e., W+AA+D). This scope recognizes that, for example, the presence of a woman enriches the diversity of a group, but the diversity increases further if she happens to be black, or further on, if she has some disabilities.

In this regard, DI calculations will count "multiple" diversities in the same person, adding them for the entire group and factored by a selected parameter. This tuning parameter has been set to 0.1 (a 10% influence for every secondary characteristic in comparison with the main diverse characteristic) as an initial estimation of the impact of such secondary diversities. Certainly, more research is required to explore the variability of this index and to set a standard, most probably depending on cultural, social, economic, and other characteristics of the environment. For the "proof of concept" attempted in this paper, we propose this as a "first guess" and the corresponding procedure.

$$DI = 1 - \frac{Dominant\ characteristic}{Total} + 0.1 * \frac{Secondary\ diverse\ characteristics}{Total} \quad (5)$$

where "Secondary diverse characteristics" are the number of individuals with a characteristic other than the dominant characteristic of the group, and other than the main diverse characteristic (i.e., in a group dominated by WAMs, a W is a main diverse characteristic, and if she is with disabilities, D becomes a secondary characteristic). Notice that the nature of the characteristic does not typify the condition of "secondary diverse characteristic" but its reference to dominant and main diverse characteristic (i.e., in a group dominated by WAMs, if one of them has a disability, D becomes a main diverse characteristic but not a secondary diverse characteristic, as in the previous example).

A sample calculation is presented in Table 4 for a group of 18 WAM (including 2 LGBQT), 1 AA male, 9 women (including 1 with disabilities, 1 AA, and 1 AA with disabilities).

Table 4. Sample calculation for the Diversity Index (DI)

Total	WAM	W	NB	AA	H	AO	LGBQT	D	FG
28	18	9	0	3	0	0	2	0	0

Primary diversities	Secondary diversities	Dominant group	Diversity Index	Minority Index
10	6	WAM	0.38	0.36

In groups dominated by WAMs, increasing the number of members brings the DI closer to the MI. The tuning parameter (i.e., 0.1) can be adjusted based on further research for a more sensitive counting of "secondary characteristics". The impact is shown in Table 5 as an example for the previous case.

Table 5. Impact of the tuning parameter for secondary characteristics

Parameter	0.0	0.1	0.2	0.3	0.4	0.5
Diversity Index	0.36	0.38	0.40	0.42	0.44	0.46

The most significant distinction and valuable application for DI is to assess the diversity of subgroups, as in the conformation of small teams within a course. An example is provided in Table 6 for the self-selection configuration of teams in the course reported in Table 4.

Table 6. Distribution of diversity in a course with self-selecting teams assessed by DI and MI

Group	Members	Dominant group	Diversity Index	Minority Index
Course	28	WAM	0.38	0.36
Team A	4	WAM	0.30	0.25
Team B	4	WAM	0.53	0.50
Team C	5	W	0.40	0.60
Team D	5	W	0.46	0.60
Team E	5	WAM	0.20	0.20
Team F	5	WAM	0.00	0.00

A graphical representation of the spread in the DI provides an illustrative approach on aggregation patterns for a particular group of students, as presented in Figure 1.

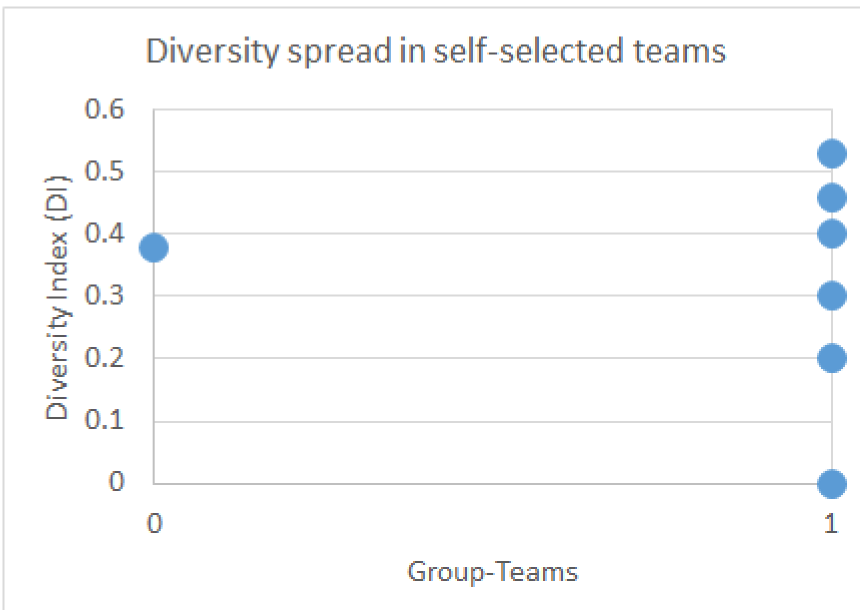

Figure 1. Spread in Diversity Index for self-selected teams

In addition to the graphical representation, the distribution of diversity among teams can be assessed in diverse ways, that could be referred to as Diversity Dispersion Index (DDI):

1. The average of the team's diversity index (i.e., 0.315) can be compared with the diversity index of the entire group. In this case there is a reduction in diversity at the conformation of the teams (i.e., 0.315 < 0.38). The standard deviation of the diversity index distribution of the team is a measurement of the spread (i.e., 0.19).

2. The difference between the maximum and minimum DI is a measure of such dispersion (i.e., 0.53 in this case). This measurement is normalized, as the entire range is 0-1. It depends only on the extreme values.

3. The previous difference can be referred to the group DI by a ratio (i.e., 1.39 in this case). It is a non-normalized measurement but with the advantage of comparing it to the former entire group. It depends only on the extreme values.

4. The differences in the sequence of teams DI can be taken to the square, added, and divided by the square of the group's DI (i.e., 0.474). It seems to be normalized, less than one, and weighing the contribution of every team.

5. The angle of spreading fixed by the maximum and minimum teams DI over an arbitrary 1-unit axis (i.e., 0.51 rad or 29.3°). This measurement can be normalized by the ratio to the maximum angle of dispersion given by the potentially extreme team DI values of 0 and 1 (i.e., 0.558)

Based on this analysis, teams can be arranged to provide a maximum level of diversity instead of that achieved by self-selection. Figure 2 illustrates a potential configuration of teams for this case. The average diversity index for the teams would have been 0.38, the same as for the group, with a standard deviation of 0.048

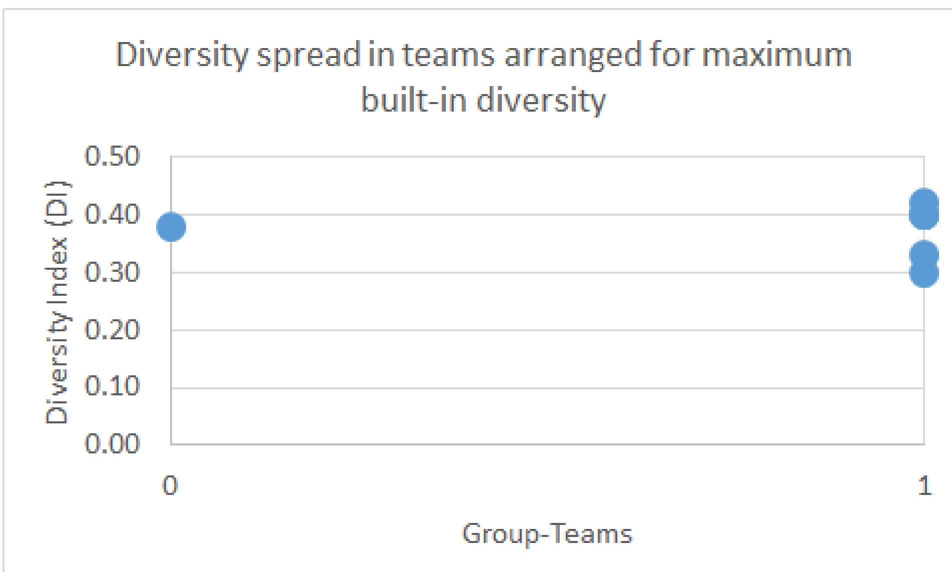

Figure 2. Spread in Diversity Index for arranged teams

Results

MIs and DIs were calculated for nine sequential courses (one every term) for the chemical engineering curriculum as presented in Table 7.

Table 7. DI and MI for nine chemical engineering courses in sequence (one every term)

Term	S19	F19	S20	Su20	F20	S21	Su21	F21	S22

DI	0.38	0.57	0.40	0.53	0.56	0.45	0.35	0.53	0.37
MI	0.36	0.56	0.39	0.56	0.55	0.46	0.35	0.52	0.36
Dominant	WAM	W	WAM	W	WAM	WAM	WAM	WAM	WAM

Seven courses were characterized by the dominant WAM attribute, as expected for current demographics in undergraduate engineering. They include those characterized by MI<0.5, and those where the dominance of the minority representation (MI>0.5) splits among different minorities (W and AO). Two courses were led by Women representation. There are minor differences in both indices when considering all groups. The values of the DI range from 0.30 to 0.56, revealing significant differences. The evolution can be clearly assessed in Figure 3.

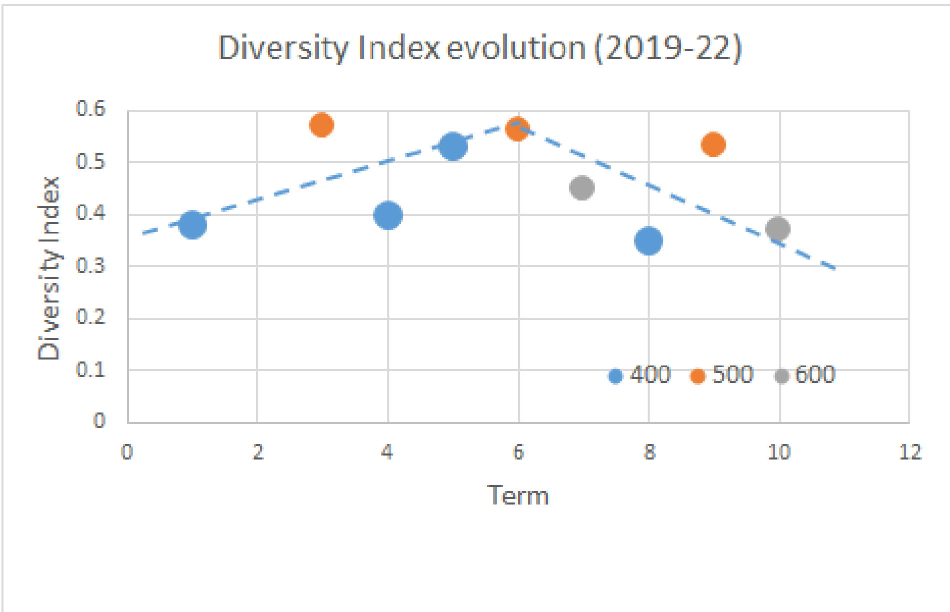

Figure 3. Evolution of the Diversity Index in 10 consecutive terms

All three courses show a decreasing trend, except for a summer course value of 400 Term 5. Students attending summer courses (5, 8) are about half of those attending spring and fall courses, building in more sensitivity for the index. When all the courses are considered in their time sequence it appears that a 5-term increase in diversity has been followed by a 4-term decrease. Course 400 is a single section, while courses 500 and 600 have two sections, with only one being reported here. A more complete analysis would require adding data for the other sections. Further research is needed to explore causes for these trends, but it is the purpose of the present paper to show the usefulness of the DI to assess such changes.

An interesting validation of the DI is presented in Figure 4 that shows that the average DI for self-selecting teams is always less than the average of the parent group, confirming a tendency to emphasize homogeneity, at least in terms of the attributes considered here.

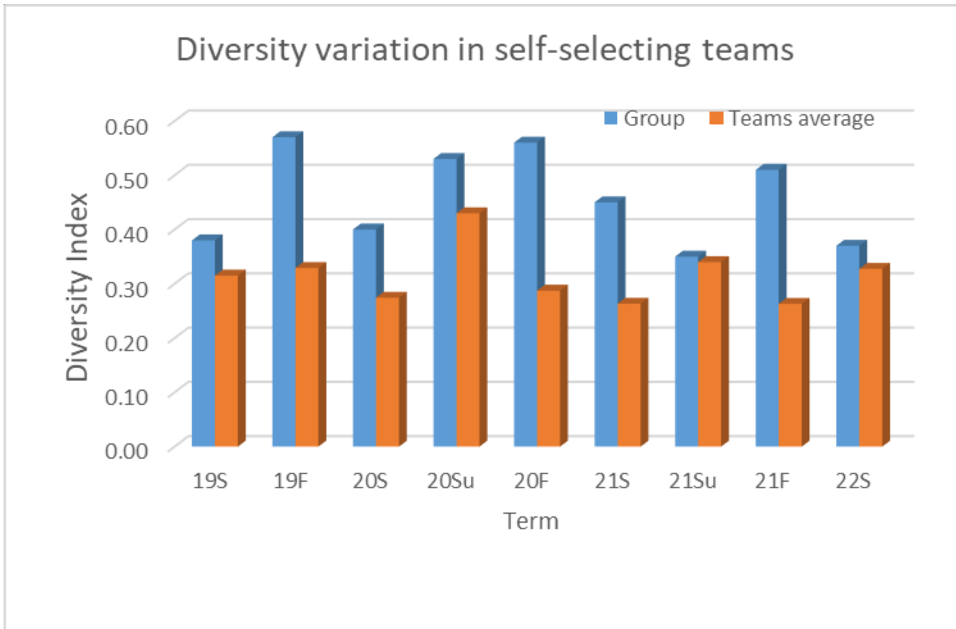

Figure 4. Impact of self-selection in diversity

The attribute of "first generation" student has been brought up as an eventual significant component for diversity for engineering education. A recent statistic at the Chemical Engineering Department shows that 10 out of 65 Junior students declared identification as first-generation (15.4%), and 20 out of 194 Senior students (10.4%). It is a non-observable characteristic and was not included in previous analysis. However, it was considered interesting to evaluate its impact and test the flexibility of the DI to accommodate other attributes. Students in one course were informally asked to identify as "first generation" students, resulting in a significant measurement (12.5%). The impact on the diversity index of the group and the teams is presented in Table 8.

Table 8. Impact of including "first generation" as a diversity attribute

FG	Group	A	B	C	D	E	F	G	H	I	J
Without	0.53	0.50	0.42	0.20	0.42	0.40	0.40	0.02	0.02	0.25	0.20
With	0.56	0.50	0.62	0.20	0.44	0.42	0.42	0.02	0.02	0.25	0.24

A most valuable potential for the development and application of the diversity index would be as a predictor of team performance. A very preliminary approach is taken here to show the potential application. Students in one of the referred courses were asked to develop a "Global Project". The initiative required students to identify a problem or need in a foreign country and assess that problem, including a potential solution, with foreign partners living or closely related to that country. The team project ran for the full term with several deliverables worth 10% of the definitive grade in the course. By the end of the term, they were asked to prepare a final presentation and a poster to be presented at a public meeting with the presence of six judges from diverse backgrounds, including academia and industry. Results are presented in Figures 5 and 6.

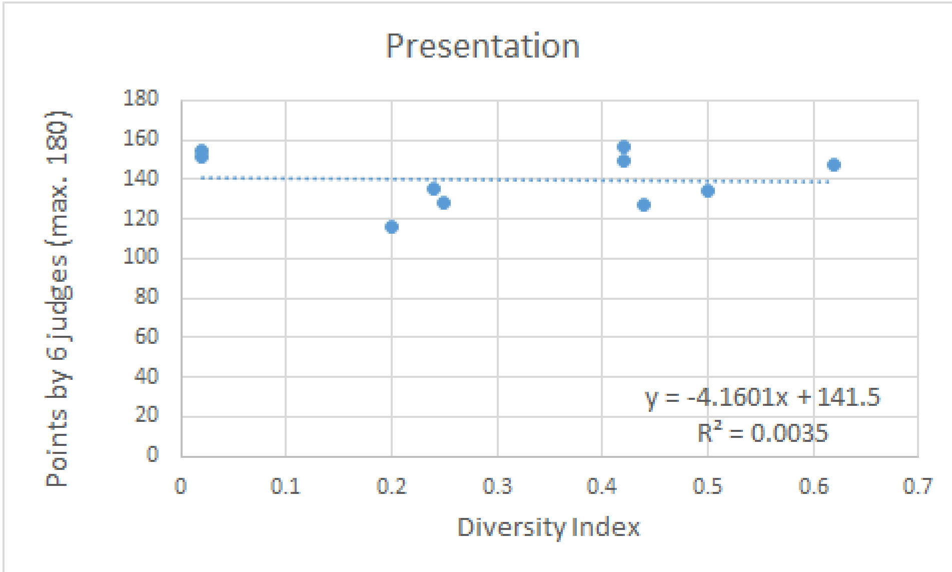

Figure 5. Impact of Diversity Index on evaluation of final presentation for a global project

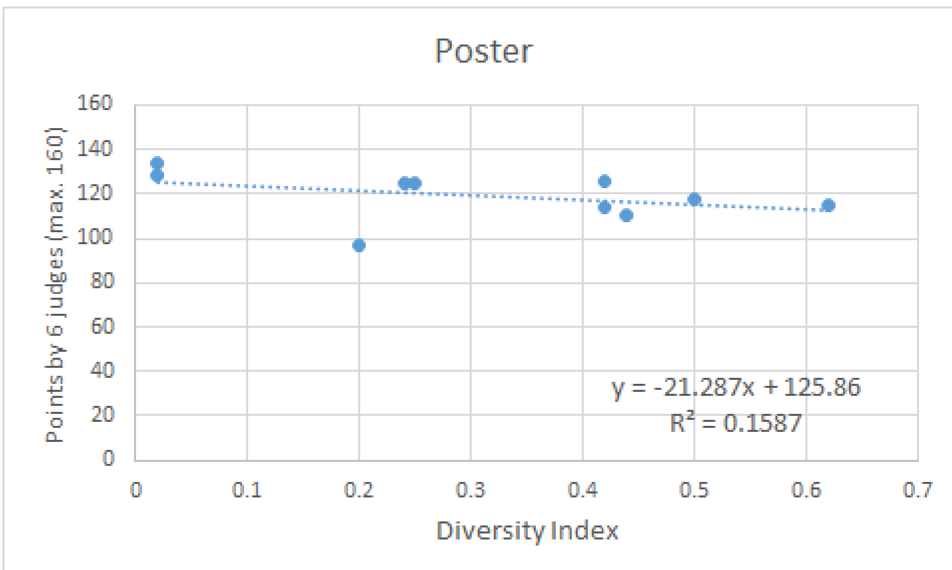

Figure 6. Impact of Diversity Index on evaluation of final poster for a global project

Though the correlation shows a poor regression coefficient, both products (poster, presentation) exhibit a trend of decreasing performance with increasing diversity index. This is no proof that diversity downgrades team performance. Other critical factors need to be added (i.e., members GPA) for a complete analysis. The detailed analysis requires further work, for example, to explore the potential cross-correlation of diversity with some other factors i.e., more diverse teams could derive from lower GPAs or concentrate members with more critical financial issues imposing more stringent constraints on cognitive load or schedule. Here we present the potential for the diversity index to measure and correlate the impact on measurable team performance indicators.

This may call the attention of faculty to integrate diversity into the scope of their courses, making more attractive for teams to self-select members that increase diversity or arrange for team configurations based on the diversity index.

Conclusions

We have proposed the DI as a useful tool to better assess quantitatively the diversity of courses and teams in college engineering courses compared to the MI. We calculated theses indices based on visible student characteristics that can be observed by instructors without taking formal surveys. We calculated the DI for eight chemical engineering courses and 69 teams within those courses. The index shows promising results on tracking the evolution of diversity with time at institutional level. It also reveals trends in the bias for self-selecting members in teams and shows the potential to be used as criteria to arrange for teams with increased diversity. At this time, we do not have sufficient data to draw meaningful correlations between DI and team performance, but this will be addressed in the future.

Future work

The significance of individual parameters on diversity needs to be developed by extended systematic research. We will propose a study based on IRB approved surveys to analyze more courses at the interdisciplinary engineering space. Other parameters (i.e., socioeconomic background) should be considered, and correlations can be proposed to identify predictors for team performance.

References

Blau, Peter M. (1977) Inequality and heterogeneity. A primitive theory of social structure. The Free Press. New York.

Harrison, D.A.; Klein, K.J. (2007). “What’s the difference? Diversity constructs as separation, variety, or disparity in organizations” The Academy of Management Review, 32 (4) http://dx.doi.org/10.5465/AMR.2007.26586096

Haveman, Heather A. (1995). “Structural Contexts of Opportunities. Peter M. Blau”. American Journal of Sociology, 101, 1, July 1995 https://doi.org/10.1086/230704

McCarthy, J. J., & Parker, R. S. (2011, June), “Evaluation and Results for an Integrated Curriculum in Chemical Engineering” Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC. 10.18260/1-2--17931

Simpson, E.H. (1949) “Measurement of diversity”. Nature, 163:688

Trytten, Deborah A; Pan, Rui; Foor, Cindy E.; Shehab, Randa l.; Walden, Susan E. (2015). 122nd ASEE Annual Conference and Exposition. #1763, June 14-17, 2015. Seattle, WA.

Usher, M.; Barak, M. (2020) “Team diversity as a predictor of innovation in team projects of face-to-face and online learners”. Computers and Education, 144 (2020) 103702 https://doi.org/10.1016/j.compedu.2019.103702

Wulf, William W. “Diversity in engineering”. Leadership and Management in Engineering, 1:4: 31-35, 2001