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# Enhancing Students' Engineering Self-Efficacy, Values, and Identity through Needs Finding and Engineering Design

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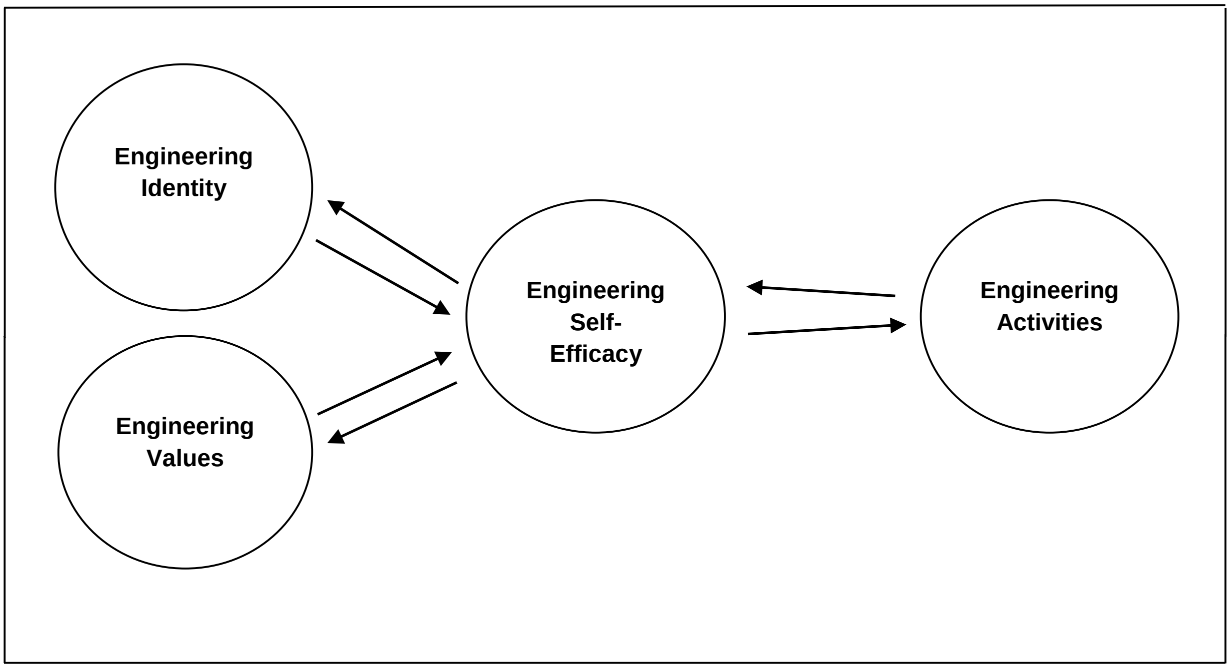
This paper reports preliminary descriptive findings from an analysis of and educational intervention that involved curricular changes that incorporated needs finding and engineering design into several (8) undergraduate (200 and 300 level) Biomedical and Chemical Engineering courses in the Spring of 2021 at a medium-sized public HBCU. It is hypothesized that allowing students to gain practice at identifying important needs and designing solutions will increase their beliefs in their own capability to do engineering (self-efficacy), which will in turn help them see themselves as engineers (identity), and promote their valuation of the knowledge, skills, and utility of the field (values).

## Background

Past research has identified an explanatory model of how Engineering Self-Efficacy, Values, and Identity combine to drive student engagement in engineering activities such as study groups, internships, design-workshops, and conferences (Walton, Knisley, McCullough, 2019). The model (see Figure 1), suggests that engineering self-efficacy is the most proximal driver of engagement and mediates the impact of engineering identity and values which are more indirect and distal motivators of engagement in engineering activities with their effects on student engagement being mediated by the more proximal influence of engineering self-efficacy. In essence, for students to be motivated to engage in engineering activities they must first feel capable within engineering (self-efficacy). Walton et al., (2019), further argue, given the right educational environment, these relationships constitute a positive feedback loop. Specifically, the more a student feels capable within engineering, the more likely they are to engage with curricular and extracurricular engineering content and activities. This increased engagement increases engineering self-efficacy, and these efficacious experiences, in turn form the building-blocks of engineering identity and promote the internalization of engineering values.

**Figure 1.** Explanatory Model of Engineering Values, Identity, Self-Efficacy, Activities




*Note:* Adapted from Walton et al., 2019

These theoretical underpinnings suggest a clear and testable hypothesis about the impact that curricular innovations that aim to incorporate needs finding and engineering design as regular elements of course curriculum should have on these motivators to student learning. Namely, such an innovation should enhance students' engineering self-efficacy and do so at a *greater magnitude* than students' engineering values and students' engineering identity. Students' enhanced beliefs in their ability to *do* engineering will in turn foster the internalization of an engineering identity and engineering values. Given these assumptions, we hypothesize that:

1) Students who complete these innovative courses will experience enhanced self-efficacy (in engineering).

2) Students who complete these innovative courses will experience enhanced engineering values, but the effect will be smaller than that of the effect on self-efficacy.
3) Students who complete these innovative courses will experience enhanced engineering identities, but the effect will be smaller than that of the effect on self-efficacy.

## Methods

Students in six undergraduate engineering courses that were reformulated to provide students with consistent opportunities to engage in needs finding and engineering design activities were administered a pre-test and post-test survey. The survey contained measures of Engineering Values, Self-efficacy, and Identity. There were six engineering self-efficacy items arranged on a 7 point Likert scale. Students' scores on these 6 items were summed to create a composite Engineering Self-Efficacy Scale (ESES) with a possible range of 7 to 42 ($\alpha$=.778; N=88)[1]. The items assess a general form of self-efficacy as well as self-efficacy directly related to engineering design with higher scores representing greater self-efficacy. There were eight engineering values items arranged on a 7 point Likert scale. Students' scores on these 8 items were summed to create a composite Engineering Values Scale (EVS) with a possible range of 7 to 56 points ($\alpha$=.889, N=88). The items assess both general and specific aspects of the field of engineering with higher scores reflecting greater valuation. There were nine engineering identity items arranged on a 5 point Likert scale. Students' scores on these 9 items were summed to create a composite Engineering Identity Scale (EIDS) with a possible range of 5 to 45 points ($\alpha$=.897, N=78). Five of the items assess engineering identity salience (i.e., readiness to perform

[1] Cronbach's *alpha* reliability statistics refer to results from students' post-test responses to the scale items.

the identity) and four of the items assess engineering identity prominence (i.e., overall importance of the engineering identity in relation to one's other identities)[2]. The Cronbach's *alpha* scores for each of these composite scales indicate the items have an acceptable degree of internal consistency[3].

## Results

Demographic characteristics of the sample are reported in Table 1. As can be seen, a large majority (76.5%) of students identified as Black or African American, with 4.7% identifying as Hispanic, 9.4% identifying as non-Hispanic White, and 9.4% identifying as Asian or Asian American. Nearly half of all students in the sample reported total household family incomes of greater than $80,000 with slightly over 20% reporting incomes of less than $40,000. Notably a large majority (67.8%) of students in the sample identified as Female. All students reported their current academic department as the Chemical, Biological, Bioengineering department.

Next we present descriptive data on change within students' scores (from pretest to post-test), on the composite Engineering Self-Efficacy Scale, the Engineering Values Scale, and the Engineering Identity Scale. As can be seen in Table 2, mean differences in students' scores on each of the scales appear to be very small. For instance, the Engineering Self-Efficacy Scale (ESES), had a possible range of scores from 7 to 42, and the total mean difference from pre-test to post-test was just .79630. This equates to a 2.34 percent increase in students' self-efficacy

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[2] Survey items are available upon request.
[3] Conventionally within the social sciences an *alpha* score of .7 is considered the threshold for a set of items to be considered sufficiently reliable (or internally consistent).

**Table 1.** Sample Demographics

| Variable | Percentage of Sample |
|---|---|
| Race/Ethnicity | |
| Black or African American | 76.5% |
| Hispanic | 4.7% |
| Non-Hispanic White | 9.4% |
| Asian or Asian American | 9.4% |
| Household Income | |
| Less than $40,000 | 20.4% |
| $40,000 to $79,999 | 38.9% |
| Greater than 80,000 | 40.7% |
| Sex | |
| Female | 67.8% |
| Male | 32.2% |
| Employment Status | |
| Working Full Time | 1.7% |
| Working Part Time | 45.8% |
| Unemployed (Looking for work) | 28.8% |
| Unemployed (Not looking for work) | 23.7% |
| Mothers Highest Level of Education | |
| High School or GED | 15.3% |
| Some College | 11.9% |
| Associates Degree | 8.5% |
| Bachelors Degree | 26.6% |
| Masters Degree | 26.6% |
| Doctoral Degree | 6.8% |
| Year in School | |
| Freshman | 30.2% |
| Sophomore | 42.9% |
| Junior | 19.0% |
| Senior | 4.8% |
| Graduate/Other | 3.2% |

Note: *N*=64 with list-wise deletion

beliefs from pre-test to post test. The Engineering Values Scale (EVS), had a slightly larger range of possible scores from 7 to 56, and the total mean difference from pre-test to post-test was just .71186. This equates to a 1.45 percent increase in students' engineering values from pre-test to post test. Lastly, the Engineering Values Scale (EIDS), had a range of possible scores from 5 to 45, and a total mean difference of .41667. This equates to a 1.19 percent increase in students' engineering identities from pre-test to post-test. These relatively small change in students' scores on each of these scales suggests that hypotheses 1-3 are not supported. Still, within the hypotheses above, it was suggested that change in students' self-efficacy should be larger than any change in students engineering values or in their engineering identity. This is at least somewhat supported in that the data does indicate a proportionately larger change in students engineering self-efficacy than in their scores on the other constructs.

**Table 2**

**Comparison of Pre-test Post-test Means in Engineering Self-Efficacy, Engineering Values, Engineering Identity**

| Scale | Difference in Means | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| ESES Post Test | .79630 | 34.7593 | 54 | 4.84840 | .65978 |
| ESES Pre Test | | 33.9630 | 54 | 5.34106 | .72683 |
| EVS Post Test | .71186 | 49.9153 | 59 | 5.79622 | .75460 |
| EVS Pre Test | | 49.2034 | 59 | 8.74106 | 1.13799 |
| EIDS Pre Test | .41667 | 35.3125 | 48 | 5.71730 | .82522 |
| EIDS Post Test | | 34.8958 | 48 | 5.75470 | .83062 |

Lastly, given what might be considered relatively large standard deviations within the pre and post-test scores for all of the scales in the analysis, we decided to investigate for any possible gender effects in relation to the degree of change in students' scores. Below we present the mean score on each of the composite scales for students' identifying as female (Table 3), and those identifying as male (Table 4). As can be seen in Table 3, on average Female students reported a small but positive change in Engineering values from pre-test to post-test (mean change = .375 on a 56 point scale. Notably the standard deviation in the change within Engineering Values (8.84) is quite large relatively speaking suggesting a great deal of variability from student to student. By contrast, on average, Male students reported a noticeably larger (although still small), positive change in engineering values with an average change of 1.06 on a 56-point scale. Similarly, we again see a rather large standard deviation (12.38), for the mean change in Male students' engineering values. In regard to Female students' Self-Efficacy we see a notable mean change of 1.82 on a 42 point scale.  This may reflect a statistically significant change and we plan to investigate this further in future analyses. In an interesting contrast, we see a notable mean change of -1.73 in Male students' reported self-efficacy. Again, this may reflect a statistically significant change (in the opposite direction and we plan to investigate this further in future analyses. Lastly, change in Female students' Engineering Identity was minimal, an average of .563 on a 45 point scale, while change in Male students' Engineering identity was even smaller, an average of .125 on a 45 point scale.

**Table 3**

**Mean Change in Engineering Values, Self-Efficacy, and Identity: Females**

| | N | Mean | Std. Deviation |
|---|---|---|---|
| Change in Engineering Values | 40 | .3750 | 8.83956 |
| Change in Engineering Self-efficacy | 38 | 1.8158 | 4.79220 |
| Change in Engineering Identity | 32 | .5625 | 3.73249 |

**Table 4**

**Change in Engineering Values, Self-Efficacy, and Identity: Males**

| | N | Mean | Std. Deviation |
|---|---|---|---|
| Change in Engineering Values | 18 | 1.0556 | 12.83136 |
| Change in Engineering Self-efficacy | 15 | -1.7333 | 5.67534 |
| Change in Engineering Identity | 16 | .1250 | 5.63176 |
| Valid N (listwise) | 14 | | |

## Conclusion and Future Directions

Although the findings above are merely descriptive and largely do not support the hypotheses, they may suggest some support for the idea that increased inclusion of needs finding and design into undergraduate courses may meaningfully impact students engineering self-efficacy. However, this impact may be noticeably different for female and male students. Relatedly, although not especially powerful or convincing, the data do support the idea that the changes in students' efficacy were larger in magnitude (positive or negative), that changes in students engineering values and identity. Overall however, the results suggest more questions than conclusions. In our future analyses of this data we plan to conduct more inferential tests of the hypotheses stated above. These analyses may include related samples t-test (if the statistical assumptions of this test are met), or its non-parametric alternative Wilcoxon Signed-Rank test. In particular, we are interested in assessing for change in self-efficacy while controlling for whether the student is male or female. We may also analyze potential change in students' engineering self-efficacy, values, and identity on the single-item level instead of using the multi-item composite scales. Specifically, it may be the case that more noticeable changes are occurring if assessed in relation to single items, but these changes are in effect muted, when considered along-side changes in the other scale items.

## References

Walton, Tobin N., Knisley, Steven B., McCullough, Matthew B. A. (2019) "Model-building in Engineering Education" *Proceedings from the 126$^{th}$ American Society for Engineering Education Conference and Exposition, Paper #26462*. https://peer.asee.org/32272