Enhancing Continuity Between Gender Diversity Interventions Using Hybrid Social Networks

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***Abstract*— Increasing gender diversity within the engineering workforce is crucial for ensuring competitive advantage in the global marketplace. Although non-systemic gender diversity interventions in engineering education report positive outcomes throughout the literature, the cumulative effect of such efforts has proven insufficient. While resource intensive mechanisms for improving coordination between offerings in order to enhance aggregate outcomes have been proposed, constrained funding environments limit the feasibility of such solutions. We have recently introduced a hybrid social networking-based framework for extending continuity between in-person programming in a work-in-progress paper. Such an approach offers the capacity to increase engagement between in-person interventions while introducing only limited marginal costs. The research described herein expands upon this effort by providing a more detailed description of the coordination effort, and also enhancing the survey pool used to examine potential barriers to participation amongst the target user population. Results from a survey of over 130 high school and college students are presented, with a particular focus on examining factors which threaten the feasibility of the proposed implementation.**

Keywords— gender diversity, first-generation, engineering pipeline, engineering recruitment

I. Introduction

Interventions aimed at addressing the underrepresentation of women within engineering workforce have received substantial attention in the recent literature [1] - [7]. The merit of such efforts extends beyond the fundamental notion of equality, as diverse perspectives help foster the requisite creativity necessary to maintain competitive advantage in the global knowledge economy [8], [9]. Although individual interventions have reported positive outcomes, the aggregate effect of such efforts has failed to yield desired results on a national scale. This is evidenced by recent graduation statistics, with only 14.8% of engineering degrees awarded to females in the United States in 2013 [10].

Recently, we have proposed a strategy for extending the success of local intervention efforts which leverages virtual social networking platforms to enhance continuity between in-person offerings [11]. Namely, existing programming is used to initialize mentoring relationships between students and STEM professionals, which are subsequently expanded upon in a virtual environment. We have also presented a survey for assessing the feasibility of implementing such a solution in light of the user preferences and privacy concerns of the target population as it relates to their social media utilization.

The research presented herein extends the literature by expanding upon this aforementioned effort originally presented in our work-in-progress paper. Namely, increased attention is devoted to the mechanisms motivating the development of the proposed coordination effort. Moreover, further discussion regarding system implementation details is provided. Finally, data gathered from the feasibility survey is presented and analyzed for an expanded respondent pool, thereby further elucidating potential barriers to implementation.

The remainder of the manuscript begins with a review of selected work proposing models describing the underrepresentation of women in engineering. Selected efforts discussing specific interventions for addressing proposed attrition mechanisms within such models are also discussed. Next, a fundamental continuity-based mechanism for describing the disparity between outcomes reported by non-systemic gender interventions and systemic-level metrics is proposed, along with details regarding the suggested solution employing social networking platforms. Survey methods and results are then presented, along with conclusions and recommendations for future investigation.

II. Review of Selected Work

A. Models Describing Female Underrepresentation

Proposed theoretical models describing female underrepresentation within STEM fields are both immense and diverse in form [12] – [15]. Recent work has enhanced the complexity of traditional frameworks, such as the "leaky pipeline" model, which describes attrition as a sequence of temporal events at which deficits in occupational awareness, cognitive skills, or support systems cause individuals to exit the educational pathway. One well-known enhancement to this model is that proposed by Watson and Froyd to describe the dynamic interrelationships between cognitive, occupational choice, and self-identity development [16]. Fundamental in this proposed improvement is the conception that the pipeline model is oversimplified, thereby focusing improvement efforts too narrowly on specific deficit-based interventions, as opposed to broad systemic endeavors.

Beddoes expanded upon this concept of oversimplification in her work on gender discourse and problemization [17]. Namely, by interpreting the dialogue existing within the engineering education literature, she developed the following four categories of problematizations used to describe female underrepresentation – 1) economic competiveness, 2) professional service and representativeness, 3) women's attributes, and 4) social justice. By highlighting the limitations of each of these categories, she suggests that wider awareness and further discussion of the hidden risks associated with such facile frameworks may lead to alternative problem formulations which better elucidate the underlying situational dynamics.

An alternative framework which similarly continues to influence the research landscape is the so-called "chilly climate" model [18], which focuses on factors which make the engineering educational experience uniquely undesirable to females. Recent work in this area includes investigation of gender-specific psychological factors, such as preferred coping methods amongst genders. For example, through an empirical study of 150 undergraduate students, Wuhib and Dotger found that female STEM majors were more likely to utilize social coping when compared to their male counterparts [19]. Moreover, they suggest that the failure of the educational system to accommodate such strategies may contribute to the underrepresentation of females.

B. Interventions Addressing Female Underrpresentation

Although current research has thoroughly documented their limitations, pragmatic implementations of intervention programming continue to reflect the proposed attrition mechanisms implied in traditional mental models. In particular, the leaky-pipeline model, with the proposed classification scheme for leakage modes suggested in [16], continues to be a valuable framework for categorizing current intervention programming. An adaptation of the figure originally presented in [16], which demonstrates the proposed leakage mode categorization to be utilized herein, is shown in Fig 1.

Using the aforementioned classification scheme, interventions may be segmented into three categories – 1) Occupational Choice Interventions, 2) Cognitive Ability Interventions, and 3) Community Building Interventions. While [16] provides a comprehensive classification of efforts published before 2007, this section will focus upon more recent programming in the context of the above taxonomy. This discussion is not intended to be comprehensive, but rather to demonstrate ongoing interest in each intervention class

Occupational choice interventions attempt to improve the diversity of the engineering educational pipeline by enhancing exposure of underrepresented individuals to engineering careers. Recent interventions within this class have begun targeting females at increasingly younger ages. For example, the Blue STEM camp utilized a project-based learning approach to increase interest amongst middle-school attendees at the five-day camp [20].

Cognitive ability interventions target particular skill deficiencies known to serve as barriers to entry into STEM.

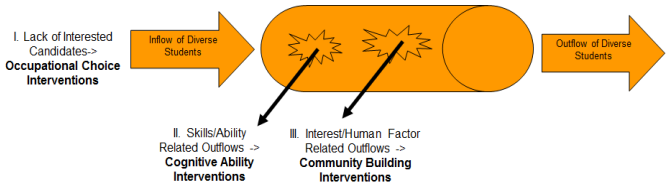

Fig. 1. Leaky Pipeline Framework for Intervention Categorization [16]

One popular class of programming within this space are mathematics bridge programs, which attempt to raise participants' mathematics placement scores in an accelerated timeframe before matriculation into undergraduate programs. For example, Tomasko et al. showed that participation in a six-week bridge program improved two-year retention rates amongst various underrepresented populations, including women [21].

Community building interventions remain a popular choice for enhancing retention amongst underrepresented groups by establishing relevant support systems within the educational environment. For example, Walton, et al. reported successful results for two interventions intended to address the aforementioned "chilly climate" encountered by women in male dominated fields such as engineering [22]. The first intervention aimed to protect the sense of belonging of females by providing a framework with which to interpret cases of adversity. The second intervention, referred to as the affirmation-training intervention, helped females mitigate stress resulting from social marginalization through incorporating aspects of their self-identity within their academic pursuits. Another popular set of programming within this class is the formulation of mentoring relationships between female college students and faculty, which have been demonstrated to reduce stereotypes regarding the male-dominated nature of STEM fields [23].

In addition to descriptions of isolated intervention efforts within the literature, more holistic assessments of general gender intervention strategies have also received attention. As an example, Liben and Coyle proposed a taxonomy of goals for such programming, which are rooted in the theories of gender development [24].

III. MOTIVATIONS

A. Proposed Attrition Mechanism

As evidenced in the previous section, isolated intervention efforts continue to report positive outcomes in the literature, which should ideally serve to address some of the aforementioned attrition mechanisms on a large scale. In spite of this, the desired gender diversity amongst engineering graduates is still lacking. Several explanations may be proposed to describe this apparent dichotomy. Fundamentally, it may be argued that the scale of such programs is simply insufficient to yield the desired results on a national level. While reasonable, such a description is only addressed by the allocation of additional resources, which may prove infeasible

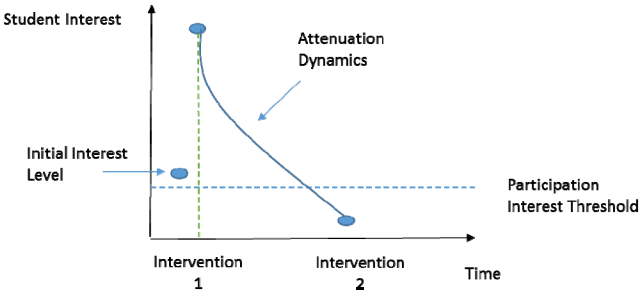

Fig. 2. Attenuation of Student Interest Between Interventions

for budget-constrained institutions. Similarly, broad efforts aimed at redesigning such programming to reflect more sophisticated mental models or to provide centralized coordination between efforts as proposed in [16] may be met with similar resource-driven objections. Moreover, a lack of awareness of such models amongst the designers of such programming may limit the feasibility of redesign efforts.

As an alternative mechanism for describing the inability of isolated occupational choice interventions to yield large-scale results, we propose a fundamental model in which participant interest in STEM fields is attenuated between in-person programming. These dynamics are described in Fig. 2, which shows a period of time encompassing two in-person interventions. Namely, at the time of the first intervention, a target student has an interest in STEM beyond a threshold corresponding to the point at which his or her perceived marginal value of attendance exceeds the associated marginal cost. Upon attendance at the intervention, interest is substantially increased, but monotonically decays over time. By the time of the second in-person offering, interest has attenuated beyond the interest threshold, thereby causing the individual in question to bypass participation in further efforts.

B. Proposed Systemic Modification

In the context of the proposed dynamics described in Fig. 2, systemic improvements may result from low-cost modifications which decrease the rate of decay between in-person offerings. With this in mind, we propose the development of a web-based architecture capable of engaging participants' interest in STEM fields between offerings. Based upon the limited cost structure associated with leveraging existing web applications, along with the proven efficacy of mentoring based efforts [25], we propose utilizing social media to achieve this means. Namely, in-person interventions serve to establish relationships between females along various stages of the STEM educational and professional pipeline, which are then translated onto existing social media platforms. As the networks exist in both the physical and virtual world, they are hereby denoted as hybrid social networks.

While such an approach offers the inherent benefit of both minimizing infrastructure cost for the sponsoring institution, along with minimizing the marginal time requirements for participants (under the assumption that they are currently active on social media), it is not without potential disadvantages. Namely, target participants may express privacy-related concerns which influence their willingness to engage in such programming, as has been demonstrated in the literature for individuals of the target age group [26]. Moreover, the proliferation of social media platforms may limit the ability to effectively serve a majority of target individuals on a limited subset of sites, thus hindering engagement amongst stakeholders. Finally, social media interactions may have limited influences on members of the target population as it relates to their occupational or educational choices. This is particularly relevant, as although certain behaviors of young adults, such as health related decisions, have been shown to be influenced through social media [27], the associated influence on educational choices may be limited [28].

IV. Methods For Assessing Feasability

The proposed hybrid social networking framework was originally suggested in 2015 in association with the planning and initialization efforts for the Women in STEMM initiative [29]. The program, hosted at Wright State University, is intended to increase gender diversity within the various STEMM degree programs offered across campus. During original discussions, it was chosen to focus in-person programming towards occupational choice interventions aimed at exposing female high school students to both general STEMM content as well as potential mentors. To address possible attrition concerns between in-person offerings associated with the model described herein, the utilization of virtual social networks was suggested as a supplement to in-person programming.

In order to examine the feasibility of the latter proposal, a survey addressing the previously discussed barriers to implementation was designed. Respondents specified their academic status (high school, undergraduate, or graduate student) and also responded to various questions related to their utilization preferences on social media through an anonymous online survey. In order to enhance the respondent pool from that originally reported in [11], the survey was sent to all female students enrolled in engineering programs at Wright State University, along with select partnering high school teachers throughout the Dayton region for purposes of distributing to their students. Using this expanded respondent pool, an additional 91 responses were obtained. Of the 132 total female respondents, 47 were high school students, 52 were undergraduate students, and 33 were graduate students.

V. Analysis of Survey Results

To begin the feasibility analysis, the specific platforms utilized by participants were investigated. As was the case in our previous work, each of the 132 respondents reported using at least one of the 14 social media sites presented in the survey. In addition, responses were again concentrated within a subset of sites. Results for the expanded respondent pool are presented in Fig. 3 for the seven most utilized platforms.

While results are similar to those originally presented for the limited pool of respondents, some clear discrepancies are noted. Namely, the newer image-based platforms (Instagram and Snapchat) exhibit increased utilization. Additionally, the

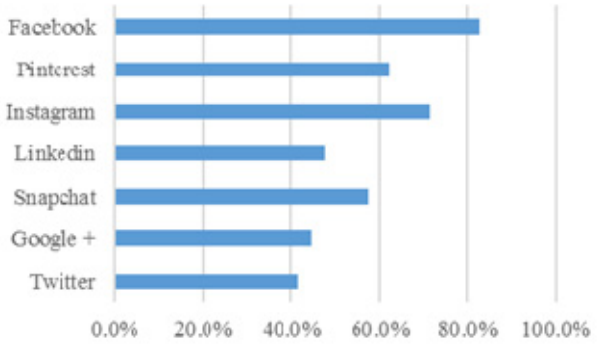

Fig. 3. Utilization of Various Social Media Platforms Amongst Respondents

percentage of Facebook users is slightly decreased when compared to the original results. Analysis of both observations indicates that each observation is attributed to a shift in the age of respondents, as the percentage of high school respondents increased from 31.7% to 35.6%.

Factors related to user privacy preferences were subsequently investigated. In our previous work, over 73% of respondents reported (as indicated by choosing "agreed" or "strongly agreed" on the standard Likert scale) that they often hesitate to add individuals to their social media accounts based upon privacy concerns. This observation was enhanced for the expanded pool, with over 78% reporting similar concerns. In general, the reported concern level was a decreasing function of educational status as demonstrated in Fig 4.

Finally, the willingness of respondents to participate in the proposed network in light of their privacy concerns was assessed. Namely, respondents were asked to use an identical Likert scale in order to rate their agreement with the following statement – "I would be comfortable connecting with STEM professionals using my current social media accounts." The percentage of respondents reporting that they either agreed or strongly agreed with the aforementioned prompt is shown in Fig. 5 versus various academic levels. The results show a monotonically increasing respondent rate versus age, although variability across classes is significantly diminished when compared to the privacy related question.

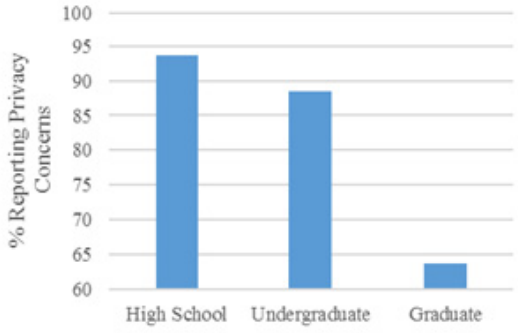

Fig. 4. Reported Privacy Concerns Versus Academic Level

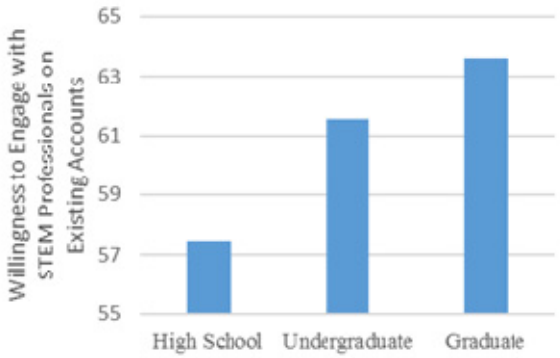

Fig. 5. Percentage Utilization of Various Social Media Platforms Amongst Respondents

VI. Conclusions

While intervention mechanisms targeted to improve gender diversity within the engineering educational pipeline continue to report positive outcomes, their aggregate effect has yet to be realized. Although theories in the literature suggest to address this proposed dichotomy through resource-intensive redesign or centralized coordination efforts, budget constraints may limit the feasibility of such proposals.

Based upon a newly introduced fundamental mechanism for describing the discontinuity between local intervention and systemic outcomes, this paper expands the literature by providing an enhanced description of a proposed hybrid social networking intervention framework for enhancing continuity between in-person intervention offerings. Namely, in-person programs are utilized to initialize relationships between engineering students and professional mentors. These relationships are then extended into the virtual domain using existing social media platforms. This approach minimizes the cost to the administering institution in terms of eliminating the need for new platform development, while also allowing target individuals to participate within the network in the context of their existing social networking activities.

Although the proposed framework offers the aforementioned cost and convenience advantages, its feasibility is dependent upon the utilization preferences of the target population. Specifically, individuals must be concentrated in a sufficiently small subset of platforms to allow requisite overlap between mentors and mentees. In addition, users must value the potential interactions and be willing to overcome privacy concerns in order to add potential mentors to their existing networks. Results from a designed survey administered to over 130 high school, undergraduate, and graduate students suggest that the target population is similarly engaged in social media when compared to individuals from the general population in the same age group. Additionally, concerns regarding privacy which are prevalent in the general population are also observed amongst respondents, with the percentage reporting concerns decreasing with age. Finally, all populations surveyed report a willingness to engage with potential mentors on existing social

media accounts, with limited variability with respect to academic status.

While the above results are promising indicators for the feasibility of the proposed modification, potential barriers to implementation are still noted. Namely, proliferation in social media platforms and the tendency of younger individuals to serve as early adopters of new technologies may limit the degree of platform overlap between mentors and mentees. Moreover, self-reported data from targeted mentees regarding limited privacy concerns may not be consistent with their behavior in practice. To truly elucidate the feasibility of the proposed intervention, results from a trial implementation should be analyzed.

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