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Adaption of the Clinical Correlation Instructional Model for 2nd Year Engineering Science Courses*

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A study is described in which the clinical correlation/integration instructional model, currently employed by Medical Schools, is adapted for the 2nd year engineering science course Mechanics of Solids. The model consists of integrating into basic applied science courses (typically taught by researchers) a number of clinical correlation lectures (taught by guest clinicians/practitioners) which illuminate the scientific principles. The idea is that this will: (i) increase student interest (which is largely in the "clinical" application and not in the theory), (ii) increase student motivation, (iii) enable students to differentiate between professional career paths, (iv) provide relevance by showing how course material can be used in practice, (v) increase student self-efficacy by providing a diversity of role models who are practitioners and not researchers. Five clinical correlation lectures were taught by dynamic, experienced, practicing engineering "clinicians" who formed a diverse mix across gender, age, and race/ethnicity. These individuals, all employed in industry, were selected from the ranks of Department Advisory Board members and alumni. The program also contained a modest mentorship component although this is not discussed here. An evaluation program, which provides gender specific results, assessed aspects of student attitudes towards the program and their perceptions of engineering. The results overwhelmingly demonstrated (i) intense interest in the program and (ii) increased motivation in the desire to become engineers. An increased understanding of career paths (differentiation) was also clearly demonstrated. Student understanding of their profession (relevance) increased and student comments on role model clearly indicated the positive effects of the program. Overall course performance improved as well, as indicated by a near halving of the drop and failing rates. The 1 year study clearly demonstrates the enormous potential of the model to positively impact engineering students in the critical 2nd year.

Keywords: university-industry collaboration; engineering science curriculum enrichment; industrial case studies; guest lecturers

1. Introduction

This article reports on a one year study of a novel curriculum enrichment program for key 2nd year, University-based engineering science[1] courses. The purpose is to address and remediate a number of instructional issues such as (i) *poor student performance*, (ii) *decreased student satisfaction (and increased student frustration)*, (iii) *lack of student motivation*, (iv) *lack of understanding of what engineers do*. The consequences to educational institutions, because of these factors, are costly and include elevated course attrition rates (especially in the first 2 years) resulting in decreased student retention and graduation rates. The negative impact on the strength and stability of our future engineering workforce because of this is likely significant. Consider for example a sampling of student performance statistics over the last 6 years or so from the first semester 2nd year course Statics and the second semester 2nd year course Mechanics of Solids[2]. The data indicates the staggering fact that, on average, 50% of students received either a D or F grade, have dropped the course, or else have registered but never attended. Furthermore, the course attrition rate (defined as the percent of students who drop or never attend) is on average 20%. Course or curricula based solutions to this critical issue, which rely on substantial decreases in class size or which involve costly structural changes, are unrealistic in the modern American research university. For these reasons any curriculum enhancements that attempt to redress this problem should be (i) *effective* in the sense that they produce a significant and measurably positive response, (ii) *sustainable* in the sense that all changes are capable of being continued with minimal long-term effort, (iii) *scalable* meaning capable of being expanded to different subjects and to different engineering programs, i.e., they are not course or discipline dependent. Optimally, they should be grounded in, or at least related to, key concepts from modern educational theories.

[1] As defined by the Accreditation Board for Engineering and Technology (ABET), applied science exclusive of basic science, mathematics, laboratory and design.

[2] Data taken from courses taught by one of the authors (AJL).

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The paradigm described in this paper is based on the notion that there is a fundamental disconnect between the educator (research oriented; often with limited industrial experience) and the students they teach, the vast majority of whom are practice-oriented and destined for a professional career in industry (as opposed to a research career). In our view the resolution is to not necessarily have practitioners teach basic applied science courses (for which they may not be best suited) but, to infuse the courses as they are currently taught with exciting, practice-oriented components to engage and motivate students. The situation is entirely analogous to the first two years of medical student training where research scientists teach many of the courses[3] to students, most of whom will become practicing physicians and not academic researchers. For example, strong parallels exist between Medical Physiology and a typical Engineering Science course and, between the two groups of students who populate these courses. Both courses a) are typically large lecture (about 100 students per course), b) form the scientific basis of professional practice, c) are taught by scientists, i.e., those with Ph.D. degrees, and not professional degree holders, d) enroll students generally working towards a professional degree and who want to practice, i.e., they do not plan to become Ph.D. scientists (either physiologists in the case of medicine or, applied mechanicians in the case of mechanical engineering). In order to make these courses relevant Physiology Instructors will introduce a modest number of Clinical Correlation/Integration lectures taught by experienced clinicians whose purpose is to provide a bridge from the fundamental scientific principles to the diagnostics and therapeutics of patient care. The premise is that this will: (i) increase student interest (which is largely in the "clinical" application and not in the theory), (ii) increase student motivation by supporting student *autonomy* (personal control), *relatedness* (need for belonging) and *competence* (capability in dealing with their environment)[4] [1], (iii) enable students to differentiate between professional career paths, (iv) provide relevance by showing how course material can be used in practice, (v) increase student self-efficacy by providing a diversity of role models, who are practitioners and not researchers, and who can offer to students social persuasion [2].

In this paper we describe the implementation of this model in one specific engineering science course with the expectation that future articles will describe attempts to scale this replicate model to other courses and disciplines. We note that, although there are case study guides available (e.g. [3]) that provide instructor and student with realistic applications of the basic theory, the purpose here is deeper in that *the aim is to bring the excitement and relevance of real engineering into the classroom*. It should also be pointed out that another aspect of the study was to bring *guest lecturer/mentors* in direct contact with small groups of students in an attempt to foster a mentoring relationship. The specifics of this aspect of the program, along with the associated assessment data, will be reported in a companion paper.

This model was carried out for the course *Mechanics of Solids* during the spring semester of the 2012 academic year. This large lecture[5] engineering science course was chosen because it (i) is central to mechanical engineering and aerospace engineering curricula, (ii) occurs in the spring semester of the second year, and (iii) has a very high attrition rate (because of this, at Syracuse University, the course is offered three times per calendar year!).

In the following section we describe the program, presented during the spring 2012 semester, in which five integrative "clinical correlation" lectures were taught by experienced engineering "clinicians", i.e., practicing *guest* engineers from industry. Also described is a comprehensive Assessment Plan. The Results section that follows presents the findings of the study and the paper closes with a Conclusions section in which key results are summarized and future directions discussed.

2. The program

2.1 Overview

Syracuse University operates within an academic year composed of two 14 week semesters roughly coinciding with the fall/winter and winter/spring seasons. Mechanics of Solids at Syracuse University is structured so that there are 4 contact hours within 3 lectures per week delivered by a faculty member. Additionally, there is 1 hour per week of Recitation, or problem solving session, delivered by a Teaching Assistant. In a typical offering there are 40 lectures per semester with the remaining two classes reserved for examinations. (The Final Examination is given outside of the 14 week lecture period.) Five Guest Lecturers were chosen from the ranks of alumni and/or Department Advisory Board members. The general criteria used to select participants were that they must be (i) prominent engineers currently working in industry, (ii) dynamic and eager to participate, and (iii) as a whole, a diverse group across gender, age, race and ethnicity. Sixty percent of the five who participated in the study were from

[3] E.g., medical physiology, microscopic anatomy, etc.
[4] Key ingredients in fostering student motivation.
[5] Typical enrollments range from 100–120 students.

Table 1. Assessment goals and the tools to evaluate them.

Goal	Tool: Pre-survey	Post-survey	Post Lecture Questionnaire	Guest E-mail Questionnaires
Student attitudes and perceptions	X	X		
Perceived value of intervention		X	X	X

underrepresented groups. Four of the lectures were technical in nature and a 5th lecture, delivered by the founder and CEO of a successful engineering company, provided general content such as the patent application process, entrepreneurship in engineering, advice on how to manage job interviews and resumes from the point of view of the employer.

2.2 Assessment

The evaluation component of the project was carried out by the Office of Professional Research and Development (OPRD) at Syracuse University. The goal of the assessment was (i) to evaluate the overall quality of the program and student satisfaction with it (*perceived value of the intervention*), and (ii) to expose any erroneous attitudes, ideas, beliefs that might be remediated by the intervention or a modification of it (*student attitudes and perceptions with regard to the discipline of engineering*). The "*intervention*", as used in this paper and throughout the period of evaluation, refers to the two aspects of the project, (i) *Lectures* and (ii) *Lecturers as role models*[6]. A third component of the intervention, *Lecturers as mentors* will be discussed in a companion paper. There are five assessment tools employed in this study. One of these deals with *Lecturers as mentors* and will not be considered further here. The remaining four consist of (i) a *pre-survey* administered pre-*intervention* during the first two weeks of the course via student email links, (ii) a *post-survey* administered post-*intervention* upon completion of the course via student email links, (iii) paper *post lecture questionnaires* administered to students following each guest lecture, and (iv) *e-mail questionnaires* to guest lecturers sent directly following his/her visit. The relationship between a specific assessment tool and a particular assessment goal is shown in Table 1. Thus, to assess the quality, value, and impact of the *lectures*, and the *lecturers as role models*, the *post-survey*, the *post lecture questionnaire*, and the *guest e-mail questionnaires* were employed. The *pre-survey* was used to assess initial attitudes and perceptions of students pre-*intervention* while the *post-survey*, containing many of the same questions as the *pre-survey* was used to assess student attitudes post-*intervention.*

All evaluation data concerning *student attitudes and perceptions with regard to the discipline of engineering* has been broken down by (i) gender and (ii) race/ethnicity. The later breakdown will not be reported as the numbers are too small to be representative.

[6] In the sense of R.K. Merton, i.e., a person who occupies a social role to which other individuals aspire [4].

2.3 Implementation

Prior to the start of the semester, guest lecturers are selected; their lecture topics chosen; and dates for the lectures fixed (this also includes travel/hotel arrangements if guests do not reside locally). The dates are added to the course syllabus and integrated into the course schedule. Photo/bio/abstract documents of each guest lecturer are created for the course website. The assessment plan is developed.

At the first meeting of the class, a description of the different components of the project is given including (i) the lecture program, (ii) the mentor (lunch) program and (iii) the assessment program.

During the second week of class, pre-survey questionnaires are sent out to students with a one-week deadline to reply. In order to encourage participation, the submission of the pre-survey counts for one quiz score (over 90% participation resulted).

During the third week of class, a folder on Black board (course website) is made available to students containing a photo, bio and abstract for each guest lecturer. Students are invited to participate in the (optional) mentor program by using an online scheduling tool.

Before each guest lecture, each lecturer is contacted electronically and their specific IT needs discussed.

After each lecture, post lecture assessment forms are collected from all students. Each guest lecturers is sent a letter requesting feedback on their experience.

At the close of the semester, post-survey questionnaires are sent out to students with a one-week deadline to reply. In order to encourage participation, the submission of post-survey counts for one quiz score (over 90% participation resulted). Standard written course evaluations are distributed to all students.

3. Results and discussion

The results are grouped according to the assessment goals described above, i.e., *perceived value of the intervention* and *student attitudes and perceptions with regard to the discipline of engineering*. In the case of the former, specific results will be presented for the two aspects of the *intervention*: *Lectures* and *Lecturers as role models*. These results are not broken down by gender as there was very little difference in the responses of male and female students. (This was not the case for many of the questions relating to *student attitudes and perceptions with regard to the discipline of engineering* and these gender differentiated results are reported below.) Overall response rates were excellent with 92% of the class participating in the *pre-survey* and 91% participating in the *post-survey*. Note that the total class size decreased during the semester due to attrition and this fact has been taken into account when computing the rates. Student response rates for individual lectures were not computed because of the difficulty in determining the instantaneous class size at the time of each lecture as some students are in various stages of dropping or withdrawing from the course. Still, the total numbers of replies following each lecture were excellent and there is no reason to believe that the rates are not consistent with those reported for the pre and post-surveys.

Note that the final subsection contains student performance statistics for the Spring 2012 offering of the course and a comparison is made with data taken from the previous offering (Spring 2011) when there was no *intervention*.

3.1 Perceived value of the intervention

The figures in this subsection (Figs. 1–4) contain student responses to statements which deal with the *perceived value of the intervention* as a whole or its components which are the *lectures* and the *lecturers as role models*. Figures 1 and 2 depict data for the *intervention* as a whole. In particular, Fig. 1 indicates student responses on the perceived value of the program and whether they wish to see it continued. Thus, students overwhelmingly stated that they agree/strongly agree that the program should continue, that it was a valuable addition to the course and, that it offers excellent content. Figure 2 explores in more detail the effect of the *intervention* on aspects of student understanding. The first 3 statements of Fig. 2 indicate that the effect of the *intervention* on student understanding was greatest when it concerned *professional possibilities* (about 90%), a bit less when it concerned *general engineering* (about 80%) and still less when it concerned *course content* (just under 60%). This is not surprising (and not even undesirable) given that many of the lectures described problems/designs that were multifaceted and required some technical material outside the course topic of mechanics of solids. Furthermore, a near unanimous number of students agree/strongly agree that the *intervention* helped them to understand what engineers do at work (statement 4). This, coupled to statement 3 of Fig. 2 ("understanding of professional possibilities"), indicates that the intervention is capable of addressing a key hypotheses (differentiation) underlying this project (see Introduction).

Figure 3 concerns the perceived value of the

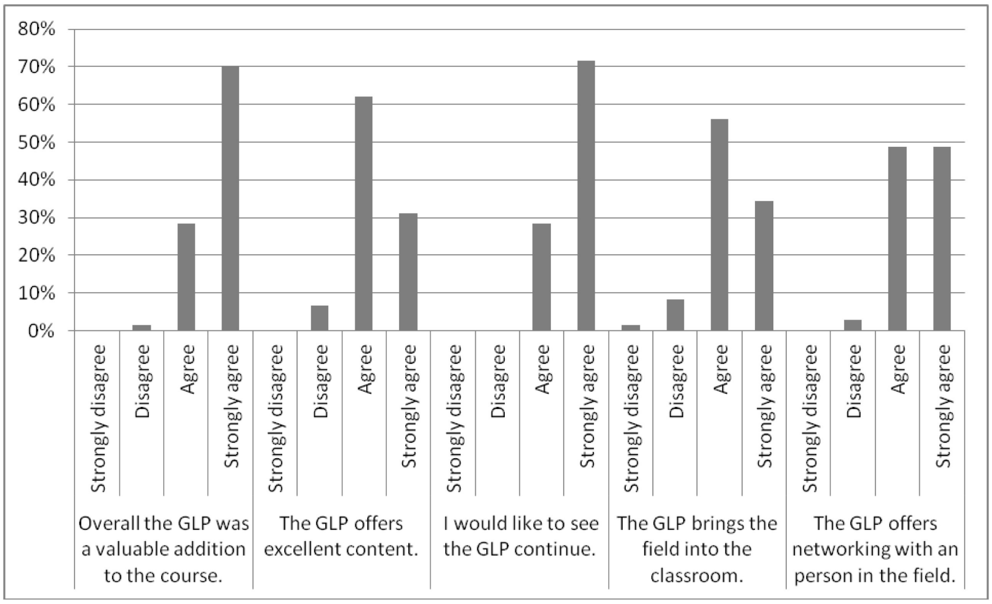

Fig. 1. Perceived value of the intervention (GLP) (GLP is Guest Lecture Program).

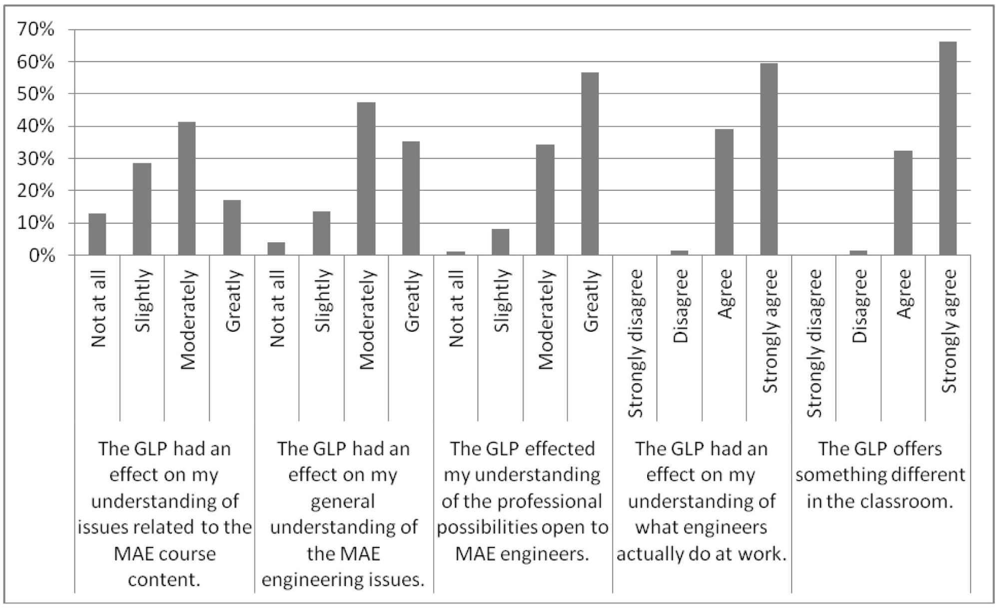

Fig. 2. Perceived value of the intervention.

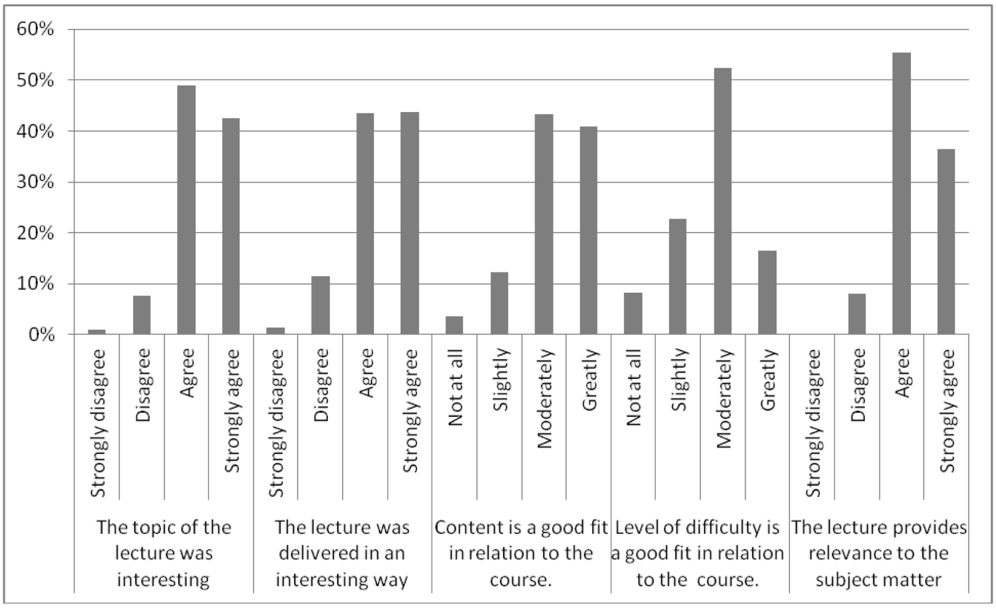

Fig. 3. Perceived value of the intervention-Lectures (Results averaged over all lectures).

lectures. All of the results displayed represent averages (over all five lectures) of the data taken from *post-lecture questionnaires* given to the entire class directly after each lecture. Student perceptions of lecture quality, relevance and fit are depicted with results that are consistent with those in Fig. 1. On lecture quality, a large majority of students felt (i) the topic of the lectures was interesting (about 90%), and (ii) the lecture was delivered in an interesting way (about 85%). On lecture fit, the figure indicates that over 80% of the students felt that *lecture content* was a good fit in relation to the course while almost 70% felt it was a good fit concerning *level of difficulty*. The later result could be truly representative or, it could be under representative due to the ambiguous phrasing of the statement. The statement will be rewritten in future offerings. On the issue of lecture relevance, the data reveals that about 90% of students agree/strongly agree that the lecture provides relevance to the subject matter. This is a clear indication that the program as structured is capable of addressing one of the key hypotheses (relevance) underlying this project (see Introduction).

Figure 4 addresses student perceptions of *lec-*

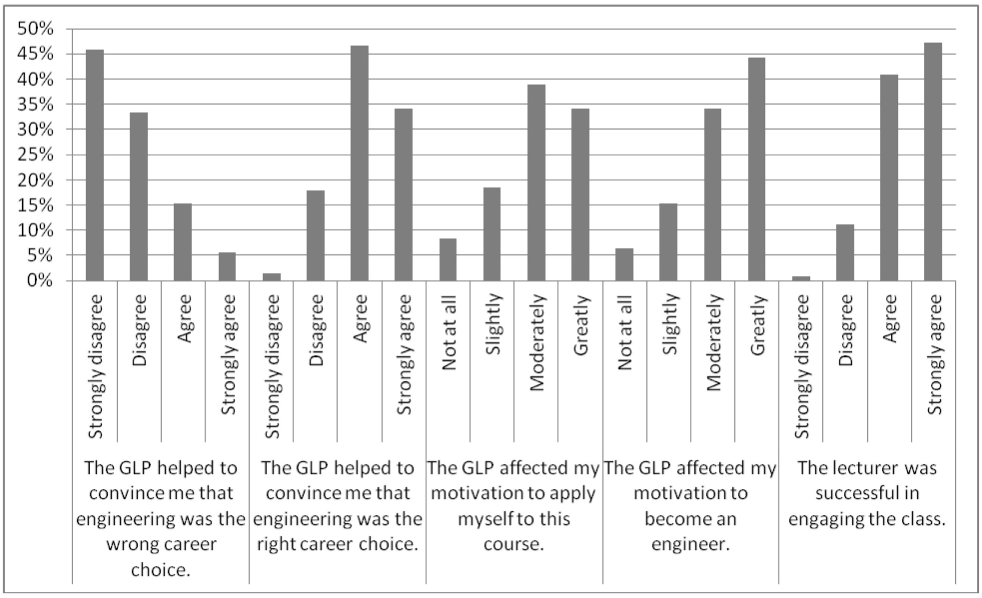

Fig. 4. Perceived value of the intervention-Lecturers as Role Models.

turers as role models. Questions relating to a lecturers' ability to help students determine if engineering is the correct (or incorrect) choice for them, a lecturers' success in engaging the class or, which speak directly to a student's motivation fall within this category. In particular, just over 80% of students agree/strongly agree that *the lecturer helped convince me that engineering was the right career choice for me* while student responses to the inverse statement *the lecturer helped convince me that engineering was the wrong career choice for me* were consistent with 79% disagree/strongly disagree. Furthermore, almost 90% of students responded that the lecturer was successful in engaging the class. On the important issue of the lecturers ability to increase motivation the figure indicates that over 70% of students felt that it was successful in both the tendency to apply oneself in the course and, in the desire to become an engineer. Thus, another of the key hypotheses underlying the program (motivation) has been perceived by students to be significantly affected in a positive way.

3.2 Student attitudes and perceptions with regard to the discipline of engineering

The results presented in this section include data dissected by either gender and/or by whether it was pre/post *intervention*. Pre-survey data (broken down by gender) on *Why I Chose to Study Engineering* was collected at the beginning of the course and this is displayed in Fig. 5. Most of these results are gender dependent[7]. An example of a gender independent result is the relatively minimal influence of parents on student choice of program of study (the role of guidance councilors in this regard is virtually non-existent for both male and female students). Another gender independent result is the role of salary with a bit more than half of both male and female students citing this in their decision to study engineering. Strongly gender dependent results include a career interest in *the design of machines/air and space craft* with 83% of male students desiring this but only 55% of female students in agreement. The difference in responses between male and female students to a related statement concerning the preference *to tinker with machines and electronics* is even more striking with 83% of male students, but only 27% of female students, in agreement. Other gender dependent results are in response to the statements *I know an engineer and I like what they do* (37% male; 9% female) and, *I like math and science* (88% male; 100% female). These results point to the fact that female students tend to go into mechanical or aerospace engineering for different reasons then male students and, their choice of career path within the profession may be different as well. In this regard female guest lecturers have the potential to strongly influence female students. This issue will require further exploration in future offerings of the program.

Figures 6 and 7 present core beliefs of students' pre and post-*intervention*. Figure 6 depicts student *core beliefs about engineering*. Statements 1 (*I have a clear idea of what engineers do at work*), 2 (*I have a good sense of the range of engineering opportunities open to me after graduation*) and 3 (*I know engineers personally and have a good idea of what their life is*

[7] Arbitrarily defined to be more than a 10% difference between male and female student responses.

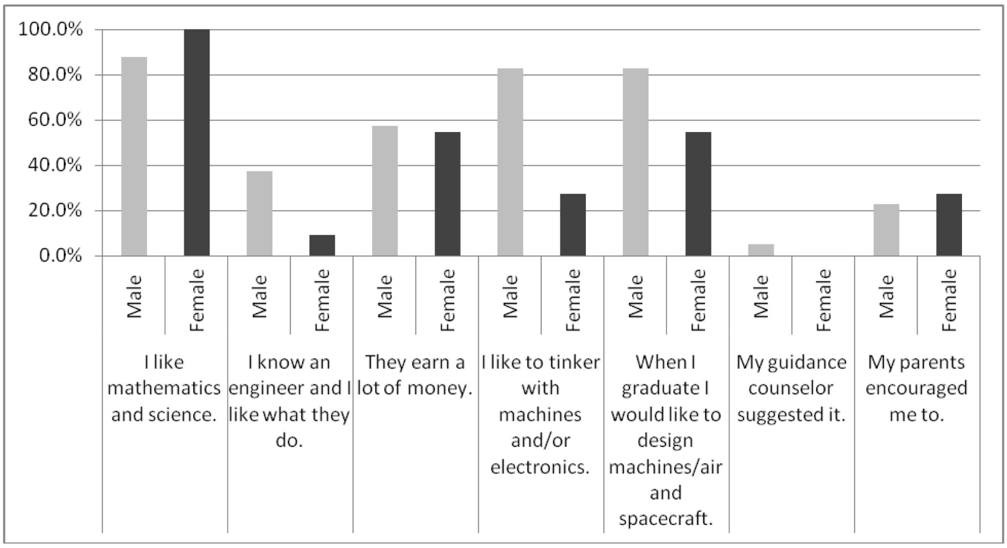

Fig. 5. Why I Chose to Study Engineering.

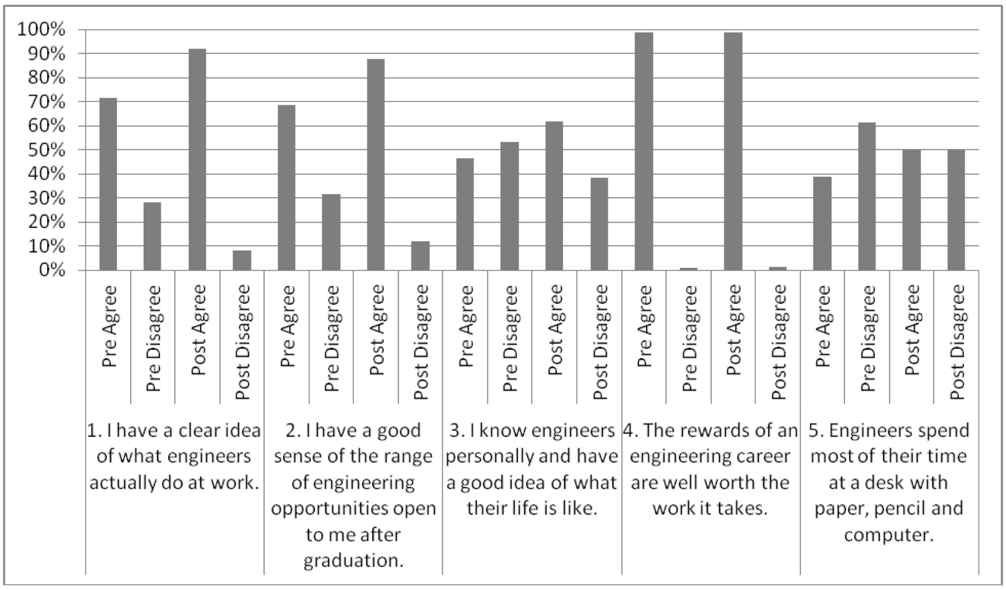

Fig. 6. Core beliefs about engineering.

like) experienced significant increases in student agreement (72% → 92% for statement 1), (69% → 88% for statement 2) and (47% → 62% for statement 3). This can be directly attributed to the *intervention*. Student responses to statement 4 (*The rewards of an engineering career are well worth the work it takes*) experienced no change pre and post-*intervention* and were near unanimous in agreement (99%). Pre-survey data for statement 5 (*Engineers spend most of their time at a desk with paper, pencil and computer*) indicated only a 39% agreement however post-survey data indicated a jump in agreement to 50%. It is hard to say whether this is a result of the *intervention* or, the theoretical nature of the course subject matter.

Figure 7 depicts student *core beliefs about engineering and me*. Statements 6 (*Engineering seems to be a good fit for my personality*), 7 (*When I entered SU I felt strongly about being an engineer*) and 8 (*I currently feel strongly about being an engineer*) experienced small declines in agreement (98% → 89% for 6, 90% → 88% for 7, 95% → 88% for 8) but still remained high reflecting the fact that the challenges some students had with this difficult course did not significantly diminish their enthusiasm to become engineers. These results, taken together indicate that students' feelings about being engineers remained unchanged (and strong) between the time they entered their program of study and pre and post-*intervention* (as will be

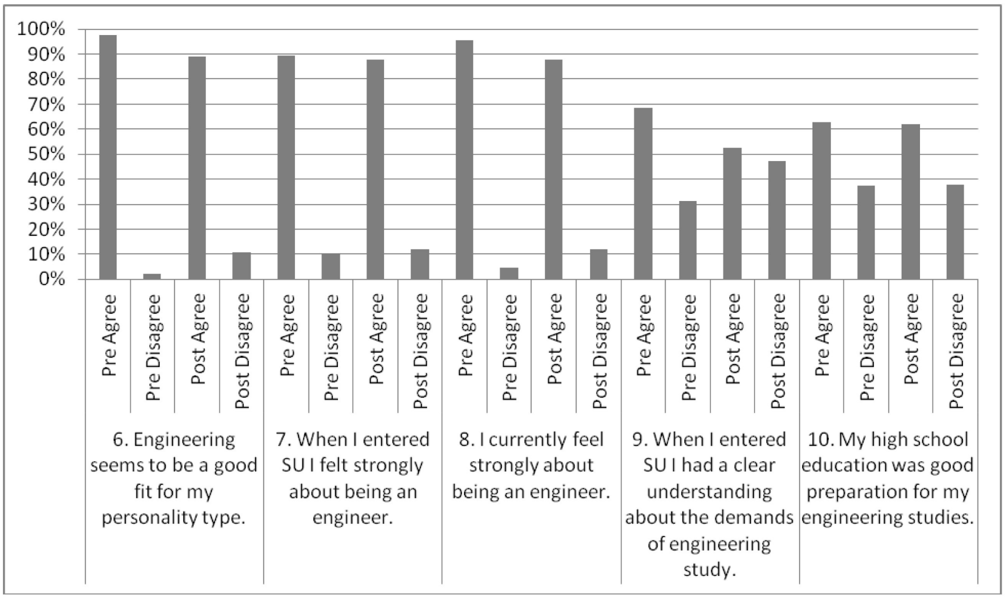

Fig. 7. Core beliefs about engineering and me.

indicated below, this result is strongly gender dependent). Statement 9 (*When I entered SU I had a clear understanding about the demands of engineering study*) experienced a drop of 16% from 69% to 53%. Student responses to the related statement 10 (*My high school education was good preparation for my engineering studies*) remained flat pre and post-*intervention* at about 62% agreement. Note that statements 1, 2 of Fig. 6 experienced the greatest increases (about 20%). To the extent that students have obtained this knowledge as a result of the *intervention*, and that this is important for 2nd year engineering students, it represents a significant success of the program.

Figures 8 and 9 are identical to the previous two figures except that they depict only responses of female students. The purpose in presenting this data is to see if, for a particular core belief, the *intervention* acts differentially on females. (Note that the gender demographics of the class is pre-survey: F/M = 13/78; post-survey: F/M = 8/67.) The figures indicate the remarkable fact that almost all of the results, with the exception of statement 4, Figs. 6 and 8 (*The rewards of an engineering career are well*

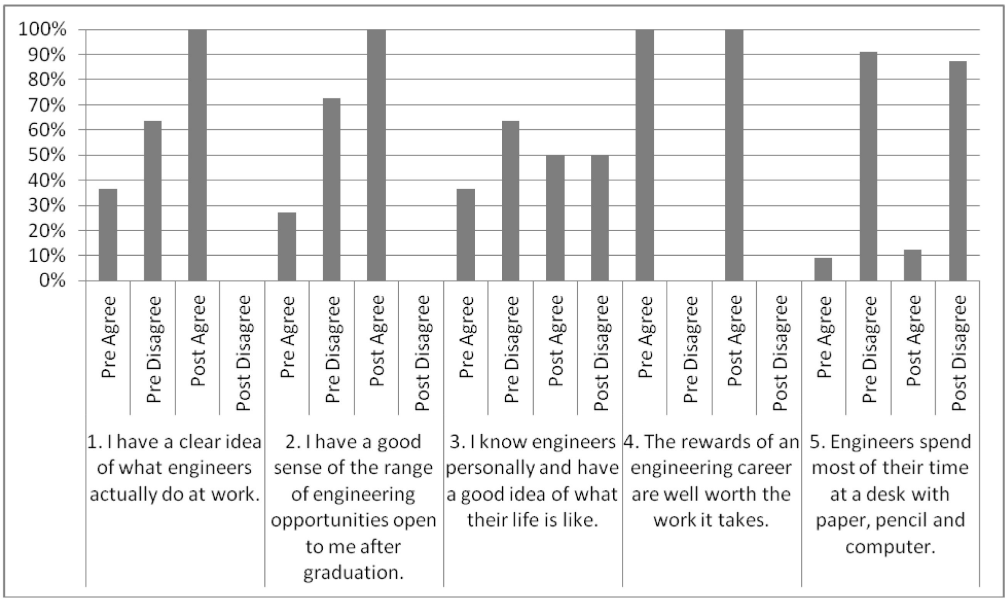

Fig. 8. Core female beliefs about engineering.

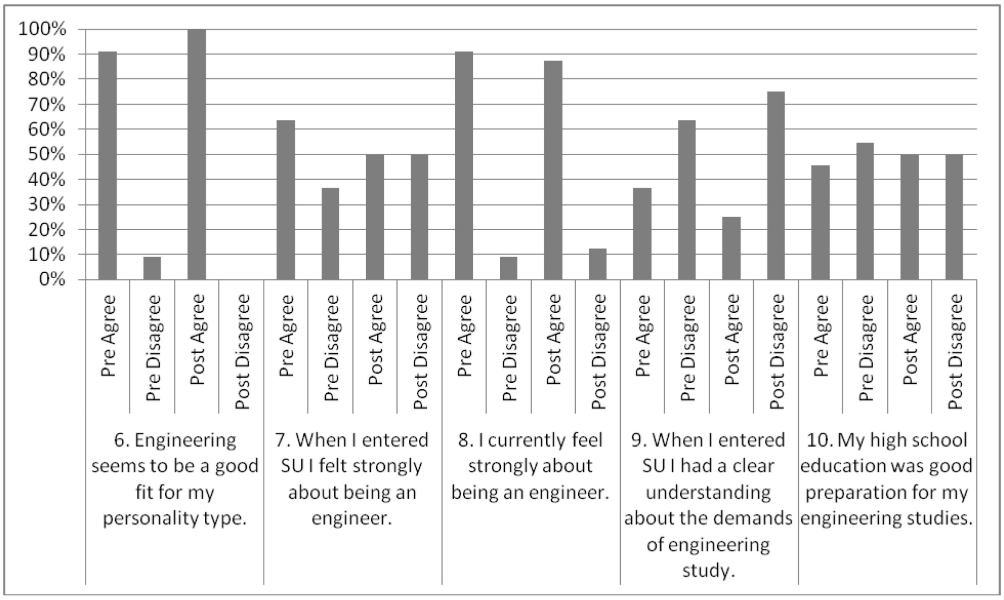

Fig. 9. Core female beliefs about engineering and me.

worth the work it takes) and 8, Figs. 7 and 9 (*I currently feel strongly about being an engineer*) are gender dependent! For these particular core beliefs students are in overwhelming agreement both pre and post-*intervention*. Two strongly gender dependent results are statements 1 (*I have a clear idea of what engineers do at work*) and 2 (*I have a good sense of the range of engineering opportunities open to me after graduation*) of Figs. 6 and 8. In this case only 36% of female students pre-*intervention* have a clear idea of what engineers do at work but 100% have a clear idea post-*intervention*. An even more striking result is that only 27% of female students pre-*intervention* have a sense of engineering opportunities open to them after graduation and this number jumps to 100% post-*intervention*! This result is strong evidence that interventions of the kind described here, while benefitting the class as a whole, can have an even greater impact on female students.

A curious result is seen in the responses to statement 5 Figs. 6, 8 (*Engineers spend most of their time at a desk with paper, pencil and computer*). Thirty nine percent of the class as a whole (which is predominantly male) responded "agree" in the pre-survey and this increased to 50% in the post-survey. However, only 9% of female students replied "agree" in the pre-survey and this remained virtually unchanged post-*intervention*. The reasons for this are unclear.

Female responses to statements 7 (*When I entered SU I felt strongly about being an engineer*) and 8 (*I currently feel strongly about being an engineer*) are substantially different from the class as a whole where it was indicated that students feelings about being an engineer remained unchanged (and strong) between the time they entered the program and pre and post-*intervention*. Statements 7 and 8 indicate that a sizable percentage of female students did not feel strongly about engineering upon entering their academic programs (statement 7) although this number jumped up to general class levels when they were asked about their current feelings towards engineering (statement 8). (Note that the discrepancy between the pre and post data for statement 7 is presumably due to attrition of female students during the course.) Furthermore, because statement 8 is true for both pre and post-*intervention* data the result is unaffected by the *intervention*. Note that while female responses to statement 7 indicate some ambivalence towards engineering, statement 8 does not. The reasons for this may be that (i) secondary schools do an inadequate job of educating female students about the rewards of an engineering career and/or (ii) the Department of Mechanical and Aerospace Engineering at Syracuse University is successful at acclimatizing female students into its ranks.

An interesting result which is strongly gender dependent is statement 9 of Figs. 7 and 9 (*When I entered SU I had a clear understanding about the demands of engineering study*). For the general student population a response of "agree" dropped by 16% from a pre-*intervention* value of 69% to 53% post *intervention*. For female students a response of "agree" dropped by 11% from 36% to 25%. While general student responses to the related statement 10 (*My high school education was good preparation for my engineering studies*) remained relatively flat (at 62%) pre and post-*intervention*, for female students the responses (while also essentially unchanged pre and post) were lower at less than or equal to 50%.

Taken together the findings presented in this subsection seem to indicate that female students enter their engineering programs less committed to engineering study than male students. Targeted efforts by female engineering professionals within the first two years, of the kind described here, at educating female students as to the nature of engineering practice may bear fruit in terms of retention of female students. This kind of interaction has been recommended as a means to improve retention of female engineering students assuming that the failure to retain arises from a variety of mechanisms. These include (i) expectations that females will be primarily responsible for family care [5], (ii) a low self-assessment of the skills required in mathematics, often in contradistinction to actual performance [6], (iii) attitudes about achievement [7] and (iv) a lack of confidence [8]. Similar findings regarding the education of students about the nature of engineering practice apply to male students as well and, although significant, are not as extreme.

3.3 Student performance statistics

Table 2 compares performance statistics for two consecutive offerings of the course during the Spring 2011 and Spring 2012 semesters. Enrollments in the two courses were similar (112 in Spring 2011; 100 in Spring 2012) and the courses were delivered in similar fashion except for the *intervention* introduced in the Spring 2012 semester. For the limited number of semesters presented the comparison indicates the potential effect of the *intervention* on performance. The data reveals that the percentage of students who drop or never attend (NA) was nearly cut in half while the percentage of students who earned a failing grade of (F) was likewise diminished by nearly a factor of 2. Furthermore, a perusal of the grade distributions presented in the table indicate that grades were raised at the bottom half of the class. It appears that the effect of the *intervention* may be that (i) more students are staying in the course (in spring 2012 15% were drop or NA; in spring 2011 28% were drop or NA), (ii) less students are failing (in spring 2012 8% were F; in spring 2011 14% were F), (iii) less students are drop+NA+F (23% for spring 2012 versus 42% for spring 2011), (iv) students are doing better (more students are getting C's and D's instead of F's, i.e., D's: 7%→19%, C's: 13.4→27%, B's remained flat but A's dropped). These results are indeed promising but more data taken from subsequent offerings of the course will need to be collected before firm conclusions can be drawn.

4. Conclusions

This paper has reported on the results of a novel curriculum enrichment program whose purpose is to address student satisfaction and retention in the critical 2nd year engineering science course *Mechanics of Solids*. As stated in the Introduction, the premise that underlies this project is that technical course related presentations/discussions involving beginning students and successful, dynamic, practicing engineers will (i) increase student interest, (ii) increase student motivation, (iii) enable students to differentiate between professional career paths, (iv) provide relevance and (v) increase student self-efficacy. Overall assessment results reported in the previous section provide strong evidence that the program does indeed benefit students in these ways. Regarding the fifth point, increasing self-efficacy, this has been commented on by numerous students who have a stronger belief in their own abilities after having observed individuals who began in similar circumstances to themselves and who are now successful. Furthermore, the results also indicate (i) overwhelming student support for this program, (ii) a significant improvement in student performance statistics over pre-program implementation data, and (iii) that a number of important student core beliefs were on the whole positively influenced by this program. Extensive comments, from students and guest lecturers, on all aspects of this program fully support the results presented in the previous section.

All of the results obtained indicate that the program described in this paper has enormous potential to benefit students during the critical second year of engineering study. However future offerings are required, with more data collected, in order to unequivocally confirm that the program is *effective*. Because no compensation was provided to guest lecturers (other than travel and hotel) the cost

Table 2. Performance statistics with *intervention* (Sp2012) and without *intervention* (Sp2011).

	% drop or NA	%F	% drop, NA or F	A	B	C	D	F
Sp2011	28	14	42	21	17	13	7	14
Sp2012	15	8	23	14	17	27	19	8

of the program is minimal and therefore has the potential to be *sustainable*. It can be readily applied to other engineering science courses within, or external to, mechanical or aerospace engineering so it is likely *scalable*. (Future work will focus on the issue of scalability by expanding the program to other engineering courses/disciplines.) Finally, the one year study contained a modest mentorship component (not discussed here) and this will need more formal development and assessment in order to foster more significant interactions for large numbers of students.

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