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Triangulated mentorship of engineering students - leveraging peer mentoring and vertical integration

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ABSTRACT: The benefits of mentorship are widely acknowledged in the literature, specifically for students from under-represented groups in technical fields of study. The authors propose a triangulation methodology for mentorship that can be adopted in engineering programmes by leveraging peer mentorship and vertical integration in a project-based learning environment. Results from a pilot programme are presented to comprehend the effectiveness of the proposed methodology. Results are evaluated quantitatively by evaluating student performance and student responses. Qualitative results are evaluated through data collected from student interviews. Results indicate that the mentorship programme outlined in this article has been highly beneficial to the cohort observed in this study. In addition to academic achievements, it is observed that students in the programme engaged in undergraduate research and actively participated in engineering student clubs since they understood the benefits of such participation for their future pursuits. Students in the pilot programme strongly acknowledge the benefits of triangulated mentorship.

Keywords: Mentorship, project-based learning, vertical integration, peer mentoring

INTRODUCTION

Mentoring is a complex, interpersonal relationship in which a mentee seeks guidance, knowledge, thoughtful reflection, encouragement and experiential counsel from a mentor [1]. Due to the complexity of the mentor-mentee relationship, it is often difficult to ascribe a mentorship role to a person of a specific rank or profile. The main requirement for such a relationship is trust, where the mentee believes that the mentor has their best interests in mind and the mentor feels confident that they can relate to the mentee's experiences and offer a thoughtful and empathetic counsel. Mentoring is often showcased as a high-impact practice in large organisations to attract potential employees and offer career advancement. In an industry setting, mentoring typically involves job shadowing and career guidance with a general outline that is formalised as per an organisation's policies [2][3]. It is argued in the literature that mentorship creates a professional connection in an organisation and allows the building of a culture of shared inquiry [4].

The benefits of mentorship are also commonly acknowledged in an academic setting, particularly for freshmen (a US term referring to male or female first-year students) transitioning to the university environment [5] or for under-represented students pursuing undergraduate or graduate degrees [6]. However, there is a lack of a standardised mentoring methodology or an agreed-upon outline for student mentorship. In the STEM (science, technology, engineering and mathematics) majors, students from under-represented groups (including those from ethnic minorities, female students and students from different socio-economic backgrounds) are seen to benefit significantly from mentoring and from the influence of potential role models serving as mentors [7]. Mentoring has been shown to specifically play a critical role in student retention and overall student engagement, since some freshmen may have a very limited knowledge of general expectations and associated components of challenging STEM majors [8]. Additionally, it could be argued that first-generation students may particularly benefit from mentorship since they often face a steep learning curve during transition from high school to the university environment.

While faculty mentorship is considered to be highly effective, there are very limited opportunities for interactions between students and faculty outside the classroom. A heavy investment of time associated with mentorship of a large number of students could also be inhibitive for some faculties. In many institutions, faculty or staff advisors are assigned to students to help them with general academic planning. However, academic advisement is limited in scope and cannot be a substitute for mentorship [9]. Furthermore, it could be argued that freshman students may find it hard to be direct with a faculty advisor in sharing their concerns or anxieties that are not purely related to the course work and the general curriculum [10].

The literature on mentoring discusses formal versus informal mentorships, as well as the need for a mentor to be intrinsically motivated [2]. The duration of mentorship, as well as the perceived benefits of carefully matching a mentor with a mentee (in terms of gender, ethnicity, etc) are also discussed, particularly in order for a mentee to relate to the mentor or for the mentor to serve as a role model and share experiences with the mentee. It is argued in the literature that a formal mentorship programme is not only beneficial to the mentee but entails substantial benefits for the entire organisation [11]. The literature also posits that mentoring may not be bound to a faculty-student relationship alone [12]. However, it is agreed that the benefits of mentoring can be maximised by providing planned or structured activities involving the mentor and the mentee [13]. Although some students may prefer a mentor from the network they develop during their transition to the university environment, it can be very challenging to find a suitable mentor [12]. Furthermore, even though best practices for successful mentorship are published in the literature, a blend of innovative practices that specifically meet the needs of the mentees is extremely important [14].

The authors propose a comprehensive mentoring methodology that incorporates a triangulation between peer-to-peer mentoring, vertically integrated mentoring and faculty mentoring. The traditional faculty mentoring and advisement model is prevalent at multiple institutions where students are required to meet their faculty mentor or advisor every semester. While effective, the authors argue that this method of mentoring alone may not serve a large segment of the student population who are perhaps seeking a role model or students who lack adequate preparation due to their socio-economic background. This problem is particularly accentuated in engineering and technology majors, where there is a significant shortage of students and faculty members from under-represented groups. The triangulation methodology proposed in this article could enhance student preparation and, at the same time, allow students to overcome some of the challenges through a multifaceted mentorship programme. The three components of the proposed triangulation are expected to complement one another and provide a holistic mentorship experience to undergraduate students in challenging STEM majors.

The aim of the proposed mentorship methodology is to augment specific aspects of the student-student relationship with the faculty-student relationship. The development of a vertically integrated cohort allows students to communicate with students with more experience, such as juniors (third-year students) and seniors (fourth-year students), to informally interact about the curriculum, coping strategies, expectations and lessons learned. The more senior students can relate to the anxieties and difficulties of the students and offer possible solutions from their own experiences. The peer-to-peer mentorship is a means of allowing students to collectively reflect on the challenges they may be facing with the curriculum or with general adjustment to the university environment. Since these students are at the same academic level, students could be expected to be honest with each other and offer solutions that are feasible and realistic. The traditional faculty-student mentorship is based on a trusting relationship where students expect the faculty mentor to listen to the mentee and provide constructive feedback while relating the student's problems to their own experiences. It is expected that these three components of mentorship will together result in a high impact on student retention and overall successful preparation for an engineering major or a STEM major in general.

The main research questions to which answers were sought in this study include whether the triangulation mentorship methodology is effective. If so, an aim of this study was to find the specific attributes of the different components of mentorship in the triangulation methodology. Quantitative as well as qualitative analysis have been performed to investigate the data collected from a group of students who participated in a pilot mentorship programme, and this was compared to a control group. Furthermore, feedback from students participating in the pilot mentorship programme has been evaluated to qualitatively assess the impact of this programme. The proposed mentorship methodology is outlined in the next section. The results from data collection are presented and conclusions are drawn in subsequent sections.

TRIANGULATED MENTORSHIP

Discussed in this section is the proposed mentorship methodology in detail; and the specific contribution of each component of triangulation is also discussed. A visual representation of the triangulation methodology is shown in Figure 1, with the components of peer mentoring, vertically integrated mentoring, and faculty mentoring.

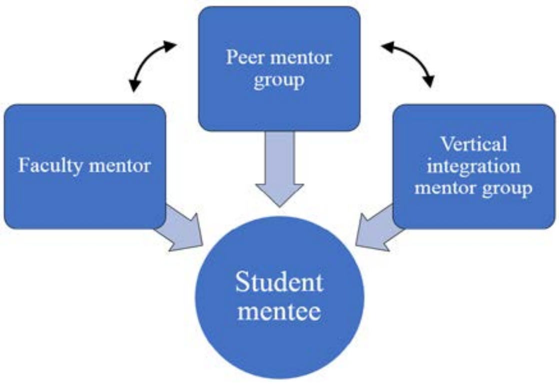

Figure 1: Mentorship methodology - triangulation.

In order to enhance cohesion among the student cohort, it is important to provide multiple opportunities, where students interact with one another. For instance, a project-based learning (PBL) environment was used in the pilot programme since it requires interdisciplinary problem-solving in teams with open-ended projects that may have multiple solutions. This will be discussed further in the next section. The peer-to-peer mentoring is expected to allow students to form a cohort, where students encourage each other and point out resources that may be helpful. The peer group is also expected to provide students with a mechanism to share concerns and anxieties since students may be expected to be less inhibited with their peers.

The peer-to-peer mentoring group consists of a cohort at the same academic level and is expected to lead to the formation of a support group that is crucial for discussing academic anxieties, difficulties with the curriculum, learning strategies and styles, and so on. This could lead to an organic means of group formation where students study together by forming learning communities or socialise with one another or encourage each other to engage in extracurricular activities that may be beneficial for their programme of study. The PBL environment could accentuate this peer-to-peer interaction since students get multiple opportunities to work with each other in open-ended projects in the classroom, as well as outside the classroom. Since the peer groups are formed such that the students in the group are from similar programmes of study, it is expected that there will be numerous opportunities for interaction between the students.

The vertically integrated mentorship entails mentorship of freshmen and sophomores (second-year students) by more senior students (juniors or seniors). The vertical integration component of mentoring is expected to provide the students with possible role models who are themselves students, and may have gone through the same struggles and difficulties, and therefore allow students to empathetically relate to each other's experiences. Furthermore, vertically integrated mentoring could allow students to plan their academic preparation based on the information received from the students who speak from their experiences in past semesters. Vertical integration also can be highly beneficial in pointing out resources, such as tutoring and the writing centre. The inhibition associated with using some of these resources can be mitigated when students hear about their benefits from more senior students, instead of the faculty. The PBL environment provides a scaffolding structure to this vertical integration since the scope of the projects is gradually ramped up as students move from the freshman year to the senior year. Directly hearing about upcoming challenges from more senior students is expected to be beneficial in preparing students.

The faculty mentorship component allows students to seek guidance for career preparation, involvement in extracurricular activities, opportunities for technical internships, and so on. While students may not be as forthcoming with the faculty mentor as they are with their peers or senior students, faculty mentorship plays a critical role since students often look up to their faculty mentor and take serious note of their advice. Faculty mentors also could actively interact with student mentors to receive constant feedback about the needs of the mentees, as indicated in the visual representation in Figure 1. It may be noted that the methodology recommended in this article does not seek to replace faculty mentoring. Instead, the triangulation proposed in this article augments faculty mentoring with other effective means of mentorship to offer guidance and encouragement while enhancing the self-confidence of the mentee. Often, there may be some redundancy between the three components of mentorship, but it is expected that this will allow reinforcement of information and advice that the students may be receiving from multiple sources. Furthermore, even though the proposed mentorship methodology is primarily aimed at freshmen and sophomore students, it can be argued that junior and senior students also can significantly benefit from their participation in the activities, either as mentees themselves or as mentors for freshmen and sophomore students.

A successful adoption of the mentorship methodology outlined in this article requires a formalised structure with individual roles assigned to faculty, as well as student mentors. The importance of a formal structure has been emphasised in the literature [15]. The mentorship programme can be structured such that a group of 15 to 30 students meets every other week for an hour, during the semester. The logistics of such sessions need to be carefully planned so that students do not see this as a class, where the instructor is going to deliver a lecture on what they should and should not do. Each session could be planned with a theme or a set of activities. However, each session should leave some room for informal contact between students or between the faculty and the students. For example, if there is a session dedicated to discussing academic difficulties that the students are facing, a 15-minute session could involve peer-to-peer discussion and another 15-minute session could involve vertically integrated discussion in smaller groups. These discussions could be conducted in small groups of three to six students, with some initial prompts from the faculty mentor. After these two sessions, 15 minutes could be left for general interactions where students talk to faculty members or peers or continue their discussion, and the last 15 minutes could be used to discuss common themes that emerged from the group discussions, with an open discussion about possible means of overcoming academic difficulties.

In some cases, students could be required to submit a reflection on the main themes discussed in the session and possible benefits of the session. Each group could be required to have a student taking notes, so that the themes that emerged from the groups are documented and appropriately addressed. The discussion can be facilitated or moderated by a faculty member, with limited intervention about suggestions or advice. In such discussions, it is important to avoid attributing concerns to a specific student and to encourage students to be frank in their interactions. Faculty mentors may not need to provide an answer to each student concern but instead the faculty mentors could turn to other students to offer possible means of overcoming difficulties or to point out resources that are available to students. It is important for students to hear about the experiences of other students since they can easily relate to one another. Each session can be concluded with a listing of academic resources that students can use; this could include tutoring services, academic counselling services, or group study venues. The themes can vary significantly from one meeting to another. Topics that may benefit students significantly, particularly in their first year at the university, are provided in Table 1, with a listing of a possible set of activities.

Table 1: Mentoring sessions - activities.

Topic	Activities
Effective studying strategies	Peer-peer mentoring; vertically integrated mentoring; group discussion
Overcoming anxieties and effective time management	Peer-peer mentoring; vertically integrated mentoring; group discussion; student testimonials
Academic resources	Information sessions from tutoring services, writing centre, mathematics tutoring centre; vertically integrated mentoring; group discussion
Test preparation	Peer-peer mentoring; vertically integrated mentoring; group discussion
Solving open-ended problems	Information session on project-based learning and engineering product development methodology; vertically integrated mentoring; peer-peer mentoring
Team work strategies	Peer-peer mentoring; vertically integrated mentoring; case studies; group discussion
Undergraduate research	Vertically integrated mentoring; student testimonials; faculty presentation
Internship experiences	Information session from career centre; student testimonials on internship experiences; vertically integrated mentoring; peer-peer mentoring
Extracurricular activities	Information on student club activities; group discussion on participation benefits; student testimonials
Counselling resources	Information session from counselling centre; discussion on reasons for stress; student testimonials; group discussion
Résumé preparation	Work session on résumé preparation and cover letter preparation; presentation from career services; student testimonials
Job search	Work session on interviewing; information on job search resources; job search tips; interviewing tips; peer-peer interviewing
Graduate school applications	Information session on application steps; funding sources; research; student testimonials

The list presented in Table 1 is not prescriptive and should be developed by each academic unit to meet the needs of their mentees. While the role of the faculty mentors is critical in co-ordinating the meetings, it is important for the faculty mentor to avoid intervening in the group discussions. The faculty mentor can limit his/her role to being a moderator and intervene only to steer the discussion or to provide the main talking points to initiate the discussion. Furthermore, additional sessions can be scheduled to discuss themes resulting from the mentorship sessions or issues brought forth by the students.

The mentorship methodology discussed in this section was used for a pilot mentorship programme that will be discussed in detail in the next section. In addition to the overall structure of mentorship discussed above, a specific form of vertical integration was carried out in the pilot programme. This involved the PBL curriculum that consists of five courses at Western Carolina University, starting with a freshman course and culminating in a two-semester Capstone project in the senior year. Team-based projects with significant hands-on content are often cited as being highly influential in student engagement and overall retention [16][17].

Although the PBL curriculum has an inherent scaffolding structure for the gradual development of teamwork skills and skills necessary for solving open-ended problems, it is commonly observed that students find projects in the junior and senior years to be significantly challenging. In order to study possible mitigation of student difficulties, the vertical integration for the pilot programme involved specific sessions to discuss the PBL curriculum for the junior and senior years. During the junior year, students are required to complete a three-credit course (ENGR 350) involving product design and development, where they deliver a prototype of a product by the end of the semester. During the senior year, students are required to complete a sequence of two three-credit courses, called as the Capstone project. Some of the vertical integration mentorship sessions in the pilot programme were allocated to discussions about student projects where students talked about their challenges and possible means of overcoming the challenges.

The primary purpose of these sessions was to inform the freshmen and sophomore students about what they can expect from the PBL projects, and how they can possibly prepare themselves during the freshman and sophomore years. Such scaffolding connects the course content in a unique manner since students are able to comprehend different levels of complexity in engineering projects. Although the nature of vertical integration could vary significantly from one institution to another, the PBL structure was particularly beneficial for vertical integration in this study.

DATA COLLECTION AND RESULTS

Discussed in this section are the qualitative and quantitative results from a study conducted to evaluate student performance, as well as student response to a pilot mentorship programme based on the triangulation methodology discussed in the previous section. This pilot programme was part of a scholarship awarded to the students through a programme funded by the National Science Foundation (NSF) and was conducted from Autumn 2014 to Spring 2018. The number of students participating in the pilot programme represented less than 5% of the students in the School of Engineering and Technology at Western Carolina University. The sample size of the pilot programme was, therefore, acknowledged to be relatively small. All data collection was conducted from February to April 2018.

Participation in the data collection was voluntary and participating students were required to sign an informed consent that was approved by the Institutional Review Board (IRB) of the University. In order to quantitatively evaluate the benefits of the mentorship programme, if any, a *t*-test was conducted. The *t*-test was used to compare the performance of students who participated in the pilot programme with students who did not participate in the programme, but had a similar academic standing, as well as a similar socio-economic status. This served as the control group for the analysis. Survey results of students who participated in the pilot programme were presented and discussed. Several responses to the survey were compared to the responses of students who did not participate in the mentorship programme. Furthermore, five students who participated in the pilot programme were interviewed in April 2018 and some feedback from these students about their experience with mentorship is presented in this section.

Students participating in the pilot programme were recruited through a selection process. The selection criteria focused on academic merit, financial need and demographics, all in equal measure. Academic merit was evaluated by using standardised test scores (SAT or ACT) and grade point average (GPA), while financial need was evaluated by assessing the shortfall calculated from the Free Application for Federal Student Aid (FAFSA) submissions. Upon acceptance, students selected for the mentorship programme were required to maintain a minimum cumulative GPA of 3.25, while maintaining a full-time enrolment (minimum of 12 credits per semester) in a degree programme in the School of Engineering and Technology. Students chosen for the mentorship programme participated in many activities involving peer-to-peer mentorship, vertically integrated mentorship, and faculty mentorship.

Some of the activities associated with the pilot mentorship programme are listed in Table 1. Students in the control group had similar academic merit and demonstrated financial need, as reported from their FAFSA submissions. However, these students did not participate in the pilot mentorship programme. Since the distribution of students into the two populations was not completely random, the results of the *t*-test cannot be generalised to larger populations with the attributes of the two groups used in this study [18]. However, the *t*-test allows a comparison between the two groups of students since the population distributions are found to be approximately normal.

Retention in the mentorship programme was 100%. Although 25% of students in the pilot programme changed their major, none of these students left the engineering/engineering technology programmes. This could be attributed partly to the mentorship programme since these students were able to discuss their academic challenges with peer mentors and faculty mentors before making any decisions about changing their major. Listed in Table 2 is a comparison of the two groups with regards to their GPA before starting at the University and their GPA in April 2018.

Table 2: Comparison between pilot mentorship group (N = 12) and control group (N = 24).

	Pilot mentorship group	Control group	*p value*
	Mean	Mean	
Unweighted high school GPA	3.57	3.49	0.46
Weighted high school GPA	4.22	4.04	0.17
University GPA (Spring 2018)	3.51	3.31	0.12

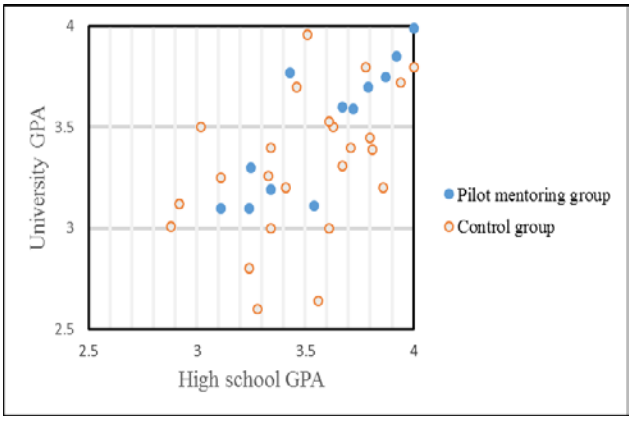

Figure 2: High school GPA versus current GPA.

In Figure 2 is shown the current cumulative GPA of all students from both groups versus their cumulative GPA when they graduated from high school. As can be seen from Figure 2, students in the mentorship programme generally performed better than the students in the control group, when comparing the groups of students starting with similar GPA from high school. The Pearson correlation coefficient between the high school GPA and university GPA of students in the mentorship programme was 0.85 as compared to a coefficient of 0.44 for students in the control group. This further indicates that students in the mentorship programme were able to maintain or exceed their level of academic achievement, whereas students in the control group demonstrated a relatively weaker correlation between their academic achievements at high school versus the university. The comparison of weighted GPA has been provided in Table 2, but has not been used for analysis since the availability of courses for calculating weighted GPA can vary significantly from one high school to another. Therefore, the weighted GPA has been listed only for reference.

The correlation coefficients clearly seem to indicate that students in the pilot programme benefited from commonly acknowledged high-impact practices such as learning communities and undergraduate research. These benefits have been reported in other studies in the literature [17], specifically in the enhancement of student engagement and overall development of cognitive skills [17][19].

Listed in Table 2 are the means for the two groups in conjunction with the *p* values from the two-tailed *t*-test. For hypothesis testing, the null hypothesis (H_0) is accepted when the two groups are statistically identical with a significance level of *p*, as reported in Table 2. When the alternate hypothesis (H_1) is accepted, the two populations are different with a significance level of 1-*p*. The *t*-test for the unweighted high school GPA is inconclusive (p = 0.46), indicating that the two groups had a similar academic standing before starting at the university. However, the cumulative GPA at the University indicates that the students in the pilot mentorship programme were performing slightly better (p = 0.12, 1-p = 0.88, 88% significance). Although these results are not conclusive by any means due to the limited sample size, it can be stated that students in the mentorship programme seem to have benefited in their overall academic standing from their participation in the programme.

In addition to GPA, some of the other parameters used to compare the two groups include participation in undergraduate research and involvement with student clubs related to the programmes of study in engineering and engineering technology. All students (100%) in the pilot mentorship programme were able to participate in at least one undergraduate research conference, and a few of these students even published at multiple venues. Although students in the pilot mentorship programme were required to participate in undergraduate research, the high level of accomplishment indicates that students were successful with their research endeavours with appropriate mentorship and guidance. In contrast, less than 10% of the students in the control group participated in undergraduate research.

Furthermore, 50% of the students in the pilot mentorship programme were active members of engineering student clubs, such as IEEE or ASME (American Society of Mechanical Engineers), as compared to less than 20% of the students in the control group. Participation in undergraduate research or extracurricular activities can be directly attributed to the exposure received by the students in the mentorship programme. Students understood the benefits of involvement in such activities directly from other students, thereby maximising the impact of sessions conducted in the pilot mentorship programme. Students in the control group may have heard about such activities from multiple sources on campus; however, they may not have completely grasped the impact of their participation in student clubs or undergraduate research.

A detailed questionnaire was used to gather data for this study to comprehend student perceptions about possible benefits of mentorship. The entire questionnaire is presented in the Appendix. The data collection for the questionnaire was carried out through a Qualtrics survey. Some of the post-processed data from student perceptions is presented in Table 3 and Table 4.

Table 3: Survey response: peer and faculty mentorship - pilot mentorship group (N = 12) and control group (N = 24).

Survey question	Pilot mentorship group response (%)				Control group response (%)			
	Very high	High	Low	Very low	Very high	High	Low	Very low
Rank the level of benefit you gained by having a faculty mentor for projects occurring outside of required coursework.	58	33	0	0	17	12	8	4
Rank the level of benefit you gained from working with a group of students to understand future course projects, such as Capstone.	42	42	8	8	46	42	8	4
Rank the level of benefit you gained from working with a group of students to understand future course requirements and rigour.	25	50	25	0	38	58	0	4

Results from Table 3 provide an interesting insight into student perceptions. Less than 50% of the students in the control group responded to the question about benefits of faculty mentorship; this could be primarily because very few students in this group would have had a faculty mentor. On the other hand, students in the mentorship programme strongly value the benefit of faculty mentorship (58% rank the level of benefits very highly and 33% rank the benefits highly).

However, for the other two survey questions in Table 3, both groups indicate a high level of perceived benefit from peer mentorship and vertical integration. It is plausible that students form their networks to work in groups or interact with more senior students, especially as they get to their junior and senior years. This implies that students clearly understand the benefits of peer mentorship. The proposed mentorship methodology outlined in this article would readily provide a network to freshmen and sophomore students that seems to be highly valued by the students.

Table 4: Survey response: project-based learning - pilot mentorship group (N = 12) and control group (N = 24).

Survey question	Pilot mentorship group response (%)		Control group response (%)	
	Yes	No	Yes	No
As a freshman or sophomore, I often met with groups of other students to discuss project work and project management strategies for ENGR 350 and Capstone projects.	83	17	46	54
As a junior or senior, I often meet with lower-year students to discuss project management strategies for ENGR 350 and Capstone projects.	50	50	54	46
The PBL programme's mentorship activities have exposed me to ideas and concepts that I may not have learned in the classroom.	83	17	-	-
The PBL programme's mentorship activities have helped me to learn from other students' experiences.	83	17	-	-

Summarised in Table 4 are the student perceptions towards project-based learning and mentorship associated with such projects. As seen from the response in Table 4, most of the students (83%) in the pilot programme had multiple opportunities to discuss open-ended projects with peers and senior students. However, it seems that opportunities for juniors and seniors to meet with freshmen and sophomores were somewhat limited. This could have been due to the composition of the cohort in the pilot programme. Also, for the last two questions in Table 4, responses from the control group clearly indicate that they have not been associated with any mentorship activities, therefore no relevant mentorship data has been reported for this group. However, students in the pilot programme seem to agree with the benefits of peer-to-peer mentorship and vertically integrated mentorship, as seen from the data in Table 4.

Five students from the pilot mentorship group were interviewed to comprehend the influence of the programme on their overall academic experience. Two of these students were females and three students were from under-represented groups. The questions were not revealed to these students before the interview, to minimise any premeditated responses. Some of the student responses about mentorship and the pilot programme are paraphrased in Table 5.

Table 5: Student response - interview.

Student	Student responses
Student A (engineering programme)	- Faculty mentorship allowed me to speak openly about issues that I was anxious about. - Mentorship from more senior students was useful to understand the scope of junior and senior courses. - Participation in undergraduate research allowed me to understand how I can tackle a large open-ended project.
Student B (engineering technology programme, changed major from engineering)	- Faculty mentorship opened my eyes to things that other students may not have been exposed to. - Peer mentorship was helpful to understand what I should expect from the programme and the resources available on campus.
Student C (engineering programme)	- Faculty mentorship was important to know about things beyond the classroom interaction. - Peer mentorship allowed me to meet other engineering students and learn more about the engineering programme. - It was surprising to know that undergraduate students could be engaged in research.
Student D (engineering technology programme)	- Faculty mentorship was helpful to know about things beyond the classroom. - Peer mentorship and vertical integration were beneficial since I have been able to get a significant amount of information that I may not have received otherwise.
Student E (engineering technology programme, changed major from engineering)	- Faculty mentorship provided access to faculty experiences and allowed me to talk openly with the faculty. - Peer mentorship and vertical integration was very valuable since I was able to learn other perspectives and gain from other students' experiences. - Belonging to a group of engineering students and faculty was a significant benefit of mentorship.

As can be seen from the student responses, the mentorship programme seems to have played a critical role in providing students with an access to peer mentors and faculty mentors. Furthermore, two of these five students mentioned in their interview that their timely decision to change majors from engineering to engineering technology may not have been possible if they did not have access to the mentorship programme.

CONCLUSIONS

In this study, triangulated mentorship has been investigated as a possible means of overcoming academic difficulties and enhancing retention in an engineering programme. Although it is acknowledged that mentorship is not the only means of overcoming academic challenges, it is argued that a well-structured mentorship programme, such as the one outlined in this article, could be one of the tools that provides a supporting mechanism to under-represented students transitioning to the university environment in a challenging STEM major. The benefits of a structured mentorship programme are readily acknowledged in the literature but there are very few student mentorship models in the literature that can be easily adopted.

Since the level of preparation of freshman students varies significantly, mentorship could be an important means of supporting students who may have the necessary academic ability but lack adequate preparation and guidance to be successful in an engineering major. A mentorship programme is expected to be particularly beneficial to first-generation students or students from under-represented groups, who may not have a role model or a mentor in the family to prepare them for academic challenges during their transition to the university environment.

Results from the pilot programme conducted for this study indicate that students participating in the mentorship programme benefited significantly from their involvement in the programme. While the findings from this study cannot be broadly generalised because of the limited sample size and limitations with the randomised selection of the students, the benefits of the mentorship programme are observed clearly by comparing the control group to the students in the pilot programme. It is seen that students in the mentorship programme significantly benefited in multiple aspects of their academic experience. Also, enhancement of confidence, mitigation of academic anxiety and judicious change of major decisions were some of the other benefits of the mentorship programme. Scaling up the mentorship programme outlined in this study can be challenging due to a heavy investment of time for the faculty, as well as the students. However, developing such a programme can be feasible if academic mentorship is integrated with honours programmes, student associations, and so on.

The focus of future studies could be on investigating the effect of mentorship on a large and diverse group of students. A robust statistical comparison between students participating in structured mentorship programmes, such as the one proposed in this article, with a control group that does not receive any mentorship also would be useful to comprehend the benefits. The specific benefits of peer mentorship and vertically integrated mentorship also could be investigated further.

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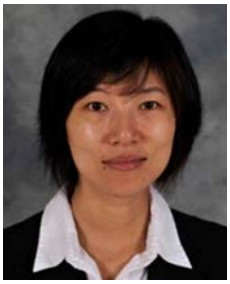
BIOGRAPHIES

Dr Sudhir Kaul is an Associate Professor of Mechanical Engineering at Western Carolina University in North Carolina, USA. Dr Kaul earned his PhD from the University of Wisconsin - Milwaukee in 2006 and has held academic positions since 2008. His research interests include dynamic modelling for vibration isolation, motorcycle dynamics, fracture diagnostics and engineering education. He has published more than fifty articles in peer-reviewed journals and conference proceedings. Dr Kaul's industry experience includes development of vibration isolation systems, and the design and development of motorcycle powertrains and hydraulic systems.

Dr Chip W. Ferguson is the Associate Dean of the College of Engineering and Technology and a Full Professor in the School of Engineering and Technology at Western Carolina University. He is an awarded teacher with 23 years of experience in higher education, where he has also held several leadership positions and worked on multiple externally funded projects. His current scholarship and funding interests are focused on improving engineering education: spatial visualisation skills, retention models and practices, mentorship and innovations in project-based learning models. Dr Ferguson's past industry experience was in the design and development of hydrostatic drive and automated fluid power systems for applications in manufacturing and agricultural environments.



Dr Yanjun Yan received her BS and MS degrees in electrical engineering from Harbin Institute of Technology (China), and the MS degree in applied statistics and the PhD degree in electrical engineering from Syracuse University. She is an Assistant Professor in the School of Engineering and Technology at Western Carolina University. Her research interests are statistical signal processing, diagnostics and particle swarm optimisation.

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APPENDIX

Table A: Survey questionnaire.

Survey question	Answer options
How many times during a normal semester did you intentionally meet with upperclassman (junior/seniors) students to discuss coursework and future course projects related to PBL or Capstone?	0/ 1/ 2/ …
I had frequent conversations with upperclassman students to ascertain future course materials and projects.	Yes/No
I feel comfortable seeking academic advice from upperclassmen.	Yes/No
As a freshman or sophomore, how frequently did you seek advice from upperclassmen?	Regularly/sometimes/ rarely/never
As a freshman or sophomore, I often met with groups of other students to discuss project work and project management strategies for ENGR 350 and Capstone projects.	Yes/No
I often meet with other students to determine project management strategies for the ENGR 350 project.	Yes/No
As a junior or senior, I often meet with underclassmen to discuss project management strategies for ENGR 350 and Capstone projects.	Yes/No
The PBL programme's mentorship activities have helped me to acquire skills by closely observing peers and senior students.	Yes/No
The PBL programme's mentorship activities have exposed me to possible opportunities (careers, internships, research, industry, campus resources).	Yes/No
The PBL programme's mentorship activities have helped me to learn from other students' experiences.	Yes/No
The PBL programme's mentorship activities have exposed me to ideas and concepts that I may not have learned in the classroom.	Yes/No
The PBL programme's mentorship activities have helped me to understand the need for good communication skills.	Yes/No
The PBL programme's mentorship activities have helped me to understand the need to strive to learn continuously.	Yes/No
The PBL programme has helped me to understand a systematic way to approach difficult engineering problems.	Yes/No
The PBL programme's mentorship activities have helped me to understand the importance of engaging in research projects.	Yes/No
I have sought engineering faculty member's mentorship for undergraduate research projects.	Yes/No
I could have never completed my undergraduate research project without the help of a faculty mentor.	Strongly agree/ agree/disagree/ strongly disagree
Rank the level of benefit you gained by having a faculty mentor for projects occurring outside of required coursework.	Very high/high/ low/very low
How often did you work with a group of students to discuss future course project requirements, such as Capstone or ENGR 350 projects, prior to taking those courses?	Every few weeks/ every month/every semester/never
Rank the level of benefit you gained from working with a group of students to understand future course projects, such as Capstone.	Very high/high/ low/very low
Rank the level of benefit you gained from working with a group of students to understand future course requirements and rigour.	Very high/high/ low/very low