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A Comparative Quantitative Study of Engagement, Learning Environment, and Educational Outcomes of High-Achieving Engineering Students*

IBUKUN OSUNBUNMI and NING FANG**
Department of Engineering Education, College of Engineering, Utah State University, 4160 Old Main Hill, Logan, UT 84322, USA.
E-mail: ning.fang@usu.edu

Studies have shown that students' college experience and involvement in academic and non-academic activities are pivotal in determining what educational outcomes they attain in college. However, little is known about how high-achieving engineering students' college experience compares with the national norm. This paper investigates the extent to which the two groups differ in terms of the quality of effort expended, college environmental emphasis, and attainment of the desired educational outcomes. It is shown that high-achieving engineering students spend more time and invest more quality effort in academic tasks than the national norm. High-achieving engineering students also make more significant progress toward the desired educational outcomes than the national norm. The perception of high-achieving engineering students about their environment is not different from the national norm. This study corroborates the theory of involvement that educational achievement is directly related to engagement.

Keywords: high-achieving engineering students; progress toward the desired outcomes of college; quality of effort; college environment

1. Introduction

1.1 Student Engagement

Researchers have studied student engagement within three domains: behavioral, emotional, and cognitive [1, 2]. Behavioral engagement, which is the focus of the present study, is defined as students' conduct, interest, participation, and involvement with academic-related activities and expectations [1, 2]. Student involvement in learning represents the quality of effort students make in utilizing resources and opportunities in their educational institution. Research has shown that student engagement in learning predicts student learning and achievement better than student demographics [3–5]. Pace [6] emphasized that the quality of students' college experience depends on the quality of effort invested. Negative, positive, non-significant, and non-linear relationships have been found between student engagement and academic attainment [7–9].

Instructors and students, however, differ in their perceptions of student engagement. Instructors tend to think that student engagement is students' responsibility, whilst students tend to believe that their engagement depends on instructors' out-of-class engagement with students [10]. Evidence shows that student engagement significantly predicts students' personal development and academic achievements [11]. It has been found that practical and innovative courses increase student engagement; whilst those courses that are too easy and considered irrelevant to students reduce student engagement [12]. Students who can control their environment are usually more engaged in learning [2]. A positive relationship exists between student involvement and intellectual and interpersonal development [13, 14]. Study shows that the quality of effort students invest in course learning predicts progress on the desired educational outcome [15].

Research suggests that student experience with academic libraries, directly and indirectly, contributes to the desired outcomes of college [16]. Although students use libraries for higher-order thinking, those who frequently use libraries usually show more work ethics than those who do not [17]. On the other hand, it has also been found that libraries do not significantly impact the gains toward the desired college outcomes. Students who invest more quality effort in student-faculty interactions, course learning, and writing experience have a more significant gain in critical thinking [18]. The more engaged students are, the better their satisfaction with their college outcomes [19].

Class attendance and hours of studies predict students' academic performance [20]. Students who work less than 20 hours outperform their counterparts. Working more than 30 hours per week can make college difficult for students [21]. Increasing the number of working hours results in a decrease in the credit hours of coursework completed by students [22].

** Corresponding author.

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1.2 College Environment

Ecological climate is the shared perception of the environment's physical, social, and institutional components [23]. The present study considers students' experiences in a college environment and the emphasis that the college environment places on student's scholarly and vocational development [4]. The college environment, in terms of climates, college activities, and student-faculty interactions, affects students' personality development [24]. In addition, cultural and social factors in a college environment influence students' transitioning experience [25]. An interactive and friendly learning environment that supports the formation of study groups encourages deep learning and students transitioning from high school to college [26–28]. These, in turn, lead to higher learning outcomes, such as critical thinking [29, 30].

The role of the instructor in creating a safe learning environment where all students can actively engage has been emphasized [31]. It has been found that there exists a moderate positive correlation between the quality of personal relationships students experience and the gains they make in their learning [32]. Campus climate influences the sense of belonging students experience on campus [33]. Students' interaction with diverse students on campus improves their self-development, social growth, and development of their capacity to later function in the diversified global [34]. Moreover, it has been found that the quality of the relationship, rather than the quantity of interaction, determine the campus environment's positive influence on a diverse group [35]. Conversely, negative interactions may have negative consequences, for instance, lower critical thinking skills [36].

1.3 The Innovation and Contribution of the Present Study

The comprehensive literature review described in the previous two sub-sections of this paper has revealed that the vast majority of existing studies on college students' experience focus on all students as a whole. Few studies focus on high-achieving college students. The latter study is important as high-achieving students set a role model for all other students to learn from. The present study fills this research gap by focusing on high-achieving students in their professional programs, particularly engineering programs that are traditionally regarded as challenging to many students. Understanding the college experience of this unique population helps design the college environment and develop policies to optimize the learning outcomes of all students.

In addition, our literature review shows that few studies have compared student experience at local institutions with national norms. Ethington & Horn [37] and Ewell & Jones [38] have emphasized the need for a comparative study of student experience at local institutions with national norms. The present study fills this second research gap by conducting a comparative study.

In the present study, students' cumulative grade point average (CGPA) is employed to indicate and measure their overall academic achievement. CGPA is a tangible measure of student achievement that directly relates to expected student outcomes set by the Accreditation Board for Engineering and Technology (ABET) in the Engineering Criteria EC 2022–23. Four ABET student outcomes addressed in the present study, either in part or in whole, include:

- An ability to communicate effectively with a range of audiences.
- An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw a conclusion.
- An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

In the remaining sections of this paper, described first are research and data collection methods, including research questions, student participants, and how data were collected and analyzed. Then, the results are described, including descriptive results, an independent t-test, and the effect size computation. Discussions are made, followed by a description of the limitations of the present study. Conclusions are made at the end of the paper.

2. Research and Data Collection Methods

2.1 Research Questions

Quantitative research was conducted to answer the following three research questions:

1. How are high-achieving engineering students different from the national norm in terms of the quality of effort they expend when engaging in college activities?
2. How are the perceptions of high-achieving engineering students different from the national norm in terms of their evaluation of the college environment?
3. How are high-achieving engineering students different from the national norm in terms of their progress toward the desired outcomes of college?

2.2 Student Participants

A total of 51 high-achieving engineering undergraduates from the authors' university, a public research institution in the Mountain West region in the United States, participated in the present study. All student participants signed the Informed Consent form approved by the Institutional Review Broad (IRB) at the authors' university.

In defining high-achieving students, researchers have considered students who have B+ to A on the U.S. letter grade scale or have a cumulative grade point average (CGPA) of 3.0 out of 4.0 [39–44]. The B+ grade represents a 3.33 GPA. In the present study, we define high-achieving students as those with a minimum CGPA of 3.5 out of 4.0.

2.3 Data Collection

The data concerning high-achieving engineering students were collected using the College Student Experiences Questionnaire (CSEQ) instrument [4]. The data concerning the national norm students were provided by the developers of the CSEQ instrument [4]. Cronbach's alpha reliability coefficient for all constructs in the CSEQ instrument varies from 0.70 to 0.92. Cronbach's alpha reliability coefficient of 0.70 indicates that a scale item consistently measures what it intends to measure [45]. The CSEQ instrument has also shown evidence for content and construct validity [4]. As such, the CSEQ instrument has been widely employed for various purposes, such as program assessment and accreditation [46].

The present study administered the CSEQ instrument to student participants online through a Qualtrics website. The CSEQ gathers data on the quality of effort students expend when engaging in college activities, the college environment factor, and the estimate of gains they make towards the desired outcomes of college during their undergraduate study.

The CSEQ constructs under the quality of effort students expend when engaged in college activities include a library, course learning, experience with faculty, writing experience, campus facilities, student acquaintances, clubs and organizations, personal experience, scientific and quantitative experience, and information in conversation. Pace [6] commented that these CSEQ constructs provide a systematic inventory of the campus experience of undergraduates.

College environment factors included in the CSEQ consist of scholarly and intellectual emphasis, vocational and practical emphasis, and quality of relationships students experienced in the college environment [4]. The progress made toward the desired outcomes of college, otherwise known as the estimate of the gain subsection in the CSEQ, includes gains in scientific and quantitative knowledge, gains in general education knowledge, gains in personal development, gains in scholarly and intellectual skills, and gains in career readiness [4].

2.4 Data Analysis

The collected data were analyzed using descriptive analysis, a summary independent t-test, and effect size computation. For the summary independent t-test, a p-value greater than 0.05 indicates that high-achieving engineering students do not differ significantly from the national norm. A p-value less than 0.05 implies that on the construct that is considered, high-achieving engineering students differ from the national norm.

Cohen's d of 0.2 is considered a small effect when interpreting the effect size between these two groups. Cohen's d of 0.5 is considered a medium effect. Cohen's d of 0.8 is considered a large effect [47]. In the present study, given all possible values of Cohen's d, we defined effect size as:

- Small if Cohen's $d < 0.35$
- Medium if Cohen's d 0.35–0.65
- Large if Cohen's $d > 0.65$

3. Results and Analysis

3.1 Descriptive Results and Analysis

Fig. 1 shows that whilst approximately 12% of national norm students spend less than 5 hours weekly on academic tasks, none of the high-achieving students spend less than 5 hours a week on academic tasks. Approximately 24% of high-achieving students spend more than 30 hours on academic tasks, whilst only approximately 5% of the national norm spend more than 30 hours weekly on academic tasks. Overall, Fig. 1 reveals that high-achieving engineering students spend more time out of class on their academic work. Studies have shown that the time spent on academic work positively correlates with students' achievement [48].

Fig. 2 reveals that no high-achieving student worked (beyond academic tasks) more than 30 hours a week; however, approximately 5% of national norm students do. Fig. 2 shows that more high-achieving engineering students work between 1-30 hours than the national norms. This work hour is considered optimum for students since there is evidence that college becomes highly challenging when students work more than 30 hours [21].

It has been noted that working long hours on a job may adversely affect students' progression and academic achievement [49, 50]. Another study

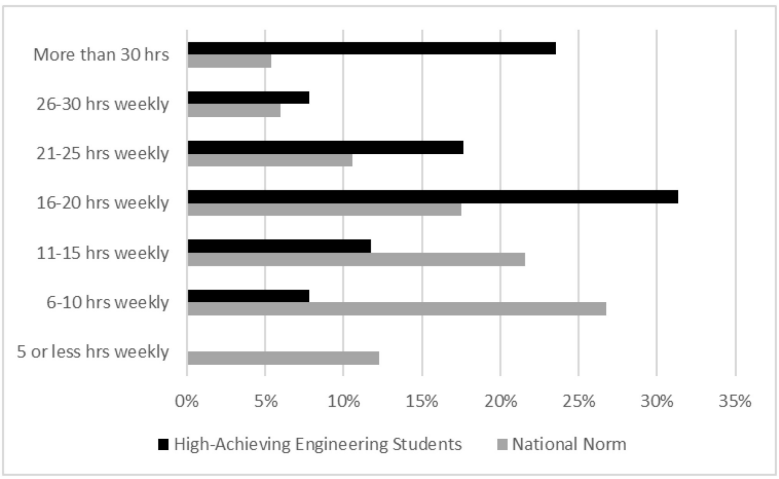

Fig. 1. Comparison of hours spent on academic work.

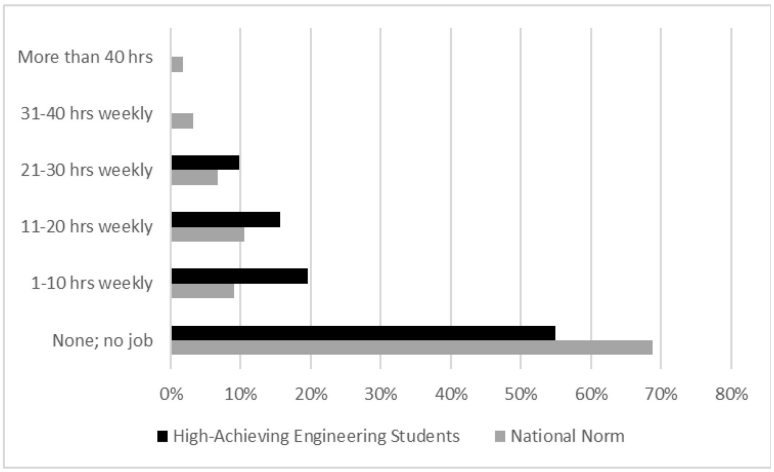

Fig. 2. Comparison of hours spent working off-campus.

shows that time spent on work does not adversely affect academic performance [48]. While there are numerous reasons why college students work in addition to taking classes, many college students must work to reduce the gap between college costs and available finances [22]. According to the United States Department of Commerce, 43% of all full-time undergraduate students in 2018 in the United States were employed. Of those students, 17% worked between 20 to 34 hours per week, and 10% worked 35 or more hours per week on average. Fig. 3 shows that none of the high-achieving students allowed their job to adversely affect their academic work; however, some national norm students reported that their job did adversely affect their academics. Combining working with a college education comes with a responsibility to balance work, school, family, and social life. If not handled properly, work may negatively affect students' achievement [22].

In comparing the experience of high-achieving engineering students with the national norm on the quality of effort they invest in college activities, on average, Fig. 4 shows that high-achieving engineering students put more effort into their scientific and quantitative experience, utilization of campus facilities, experience with faculty, involvement with clubs and organization, and information in conversation experience. However, they invest less effort in activities related to student acquaintances, personal experience, use of the library, and writing experience. Both high-achieving engineering students and the national norm invest similar quality of effort in their course learning activities.

It should be noted that while some quality of effort construct is directly related to intellectual and academic activities, others are related to non-academic ones. Some qualities of effort are both academic and non-academic. The quality of effort directly related to the academic effort includes course learning, use of the library, experience with faculty members, writing experience, scientific and quantitative experience, and information in conversation. The quality of effort regarding non-

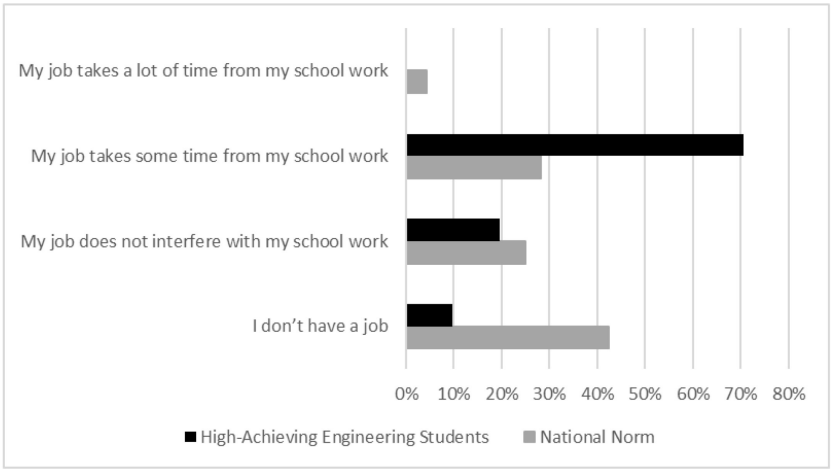

Fig. 3. Comparison of interference of job with academic work.

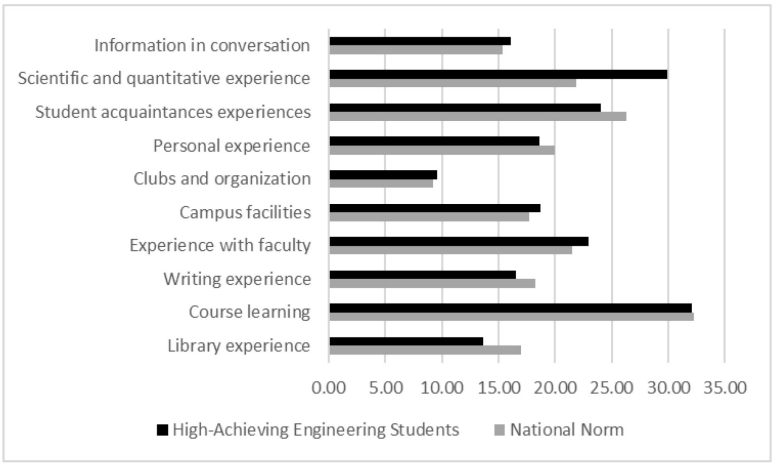

Fig. 4. Comparison of quality of effort.

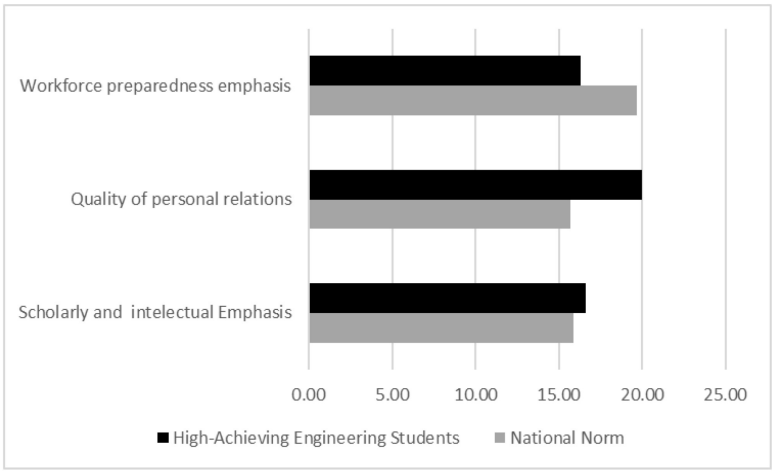

Fig. 5. Comparison of college environment emphasis.

academic activities and opportunities for personal experience includes club and organization, personal experience, and student acquaintances. Using campus facilities captures the academic and non-academic quality of student effort.

Fig. 5 compares the perception of high-achieving engineering students and the national norm on what their college environment emphasizes. In comparing the perception of high-achieving engineering students with the national norm on the

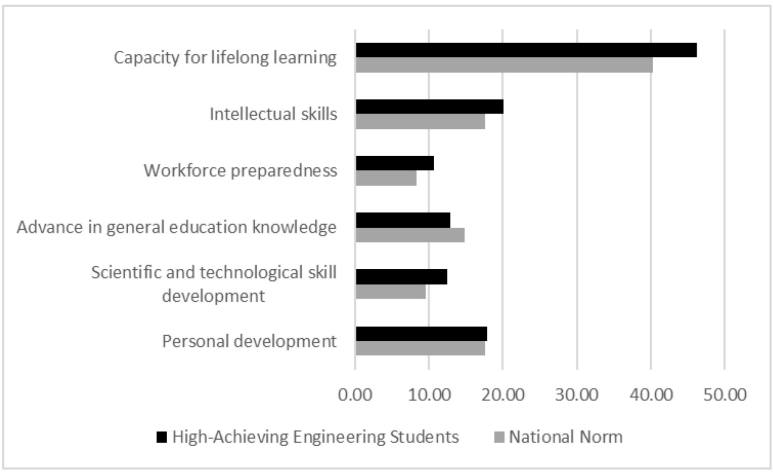

Fig. 6. Comparison of progress made toward the desired outcomes of college.

extent to which their college emphasizes certain constructs, overall, high-achieving engineering students perceive that their college places more emphasis on scholarly-related activity and personal relation construct. However, the national norm is that students believe their colleges emphasize their workforce preparedness more.

Fig. 6 compares the progress made toward the desired college outcomes by high-achieving engineering students and the national norm. In comparing the progress made by high-achieving engineering students and the national norm toward the desired outcomes of college, high-achieving engineering students made more progress regarding capacity for lifelong learning, intellectual skills, workforce preparedness, scientific and technological skill development, and personal development. Only in the case of advances in general knowledge does the national norm make more progress than high-achieving students.

3.2 Summary Independent T-test

Table 1 is the summary independent t-test comparing high-achieving engineering students with the

Table 1. Independent t-test and Cohen's d

	High-Achieving Engineering Students			National Norm						
College Experience	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**t**	**df**	**p**	**Cohen's d**
Quality of effort factor										
Library experience	51	13.67	3.19	85,749	16.98	4.62	–5.12	85,798	0.000	0.717
Course learning experience	51	32.08	4.79	85,010	32.24	5.70	–0.14	85,059	0.893	0.028
Writing experience	51	16.55	2.63	86,021	18.23	4.26	–2.82	86,070	0.005	0.394
Experience with faculty	51	22.98	6.22	85,379	21.55	6.15	1.61	85,428	0.107	0.233
Campus facilities	51	18.67	4.30	85,337	17.74	4.80	1.49	85,386	0.137	0.194
Clubs and organizations	51	9.55	3.26	85,810	9.24	4.09	0.52	85,859	0.601	0.076
Personal experience	51	18.61	4.33	85,596	19.93	5.21	–1.79	85,645	0.074	0.253
Student acquaintances experience	51	24.06	5.55	85,204	26.32	6.87	–2.28	85,253	0.023	0.329
Science and quantitative experience	51	29.92	5.61	85,083	21.90	7.72	7.42	85,132	0.000	1.039
Information in conversations	51	16.12	3.14	85,335	15.41	3.70	1.35	85,384	0.177	0.192
College environment emphasis factor										
Scholarly and intellectual emphasis	51	16.61	2.65	85,774	15.86	3.17	1.56	85,823	0.118	0.237
Quality of personal relations	51	19.98	4.30	85,801	15.70	3.37	1.26	85,850	0.208	1.270
Workforce preparedness emphasis	51	16.29	2.74	85,583	19.68	4.45	0.48	85,632	0.634	0.762
Estimate of gains factor										
Gains in personal development	51	17.86	3.51	84,813	17.55	3.90	0.73	84,862	0.464	0.080
Gains in science & technology	51	12.43	2.55	85,079	9.61	3.27	6.06	85,128	0.000	0.863
Gains in general education knowledge	51	12.94	3.13	85,040	14.76	3.98	–3.39	85,089	0.001	0.457
Gains in workforce preparedness	51	10.67	1.58	85,286	8.27	2.17	7.79	85,335	0.000	1.106
Gains in scholarly skills	51	20.06	3.08	84,379	17.56	3.72	4.82	84,428	0.000	0.672
Capacity for lifelong learning	51	46.16	6.85	83,441	40.23	7.81	5.42	83,490	0.000	0.7593

national norm. Summary independent t-test was conducted to check if high-achieving engineering students were statistically significantly different from the national norm relating to their college experience.

Considering the p-value in Table 1, it can be seen that high-achieving engineering students differ statistically significantly from the national norm in terms of library experience, writing experience, student acquaintances, scientific and quantitative experience, gains in scientific and technological skills, gains in general education knowledge, gains in workforce preparedness, gains in scholarly and intellectual skills, and capacity for lifelong learning. However, high-achieving engineering students are similar to the national norm on other constructs.

3.3 Effect Size Computation

The summary independent t-test indicates whether there exists a statistically significant difference between high-achieving engineering students and the national norm. The effect size represented by Cogen's d in the last column of Table 1 indicates the magnitude of the difference between the two groups.

As shown in Table 1, the difference is large between high-achieving engineering students and the national norm in library experience, scientific and quantitative experience, quality of personal relations, workforce preparedness emphasis, progress made on workforce preparedness, progress made on scientific and quantitative skills, progress made on intellectual and scholarly skills, progress made on workforce preparedness, and capacity for lifelong learning. The difference is moderate between the two groups in terms of writing experience, student acquaintances, and gains in general education knowledge is moderate. The difference between the two groups is small in terms of course learning, experience with faculty, use of campus facilities, involvement with clubs and organizations, personal experience, and information in conversation.

4. Discussion, Recommendation, and Limitations of this Study

4.1 Discussion

In answering the research question as to whether high-achieving engineering students differ from the national norm in terms of quality of effort, their perception of their college environment, and estimate of gains, descriptive statistics, independent t-test, and effect size computation were utilized. It is clear from this study that high-achieving students are different from the national norm in several aspects.

In terms of quality of effort when engaged in college activities, high-achieving engineering students are different from the national norm in terms of library experience, writing experience, student acquaintances experience, and scientific and quantitative experience. However, both groups expend the same effort regarding course learning, experience with faculty, use of campus facilities, involvement with clubs and organizations, personal experience, and information in conversation.

The effect size computation shows that the difference between the two groups in terms of library experience and scientific and quantitative experience is large. While high-achieving engineering students significantly expend more effort in college activities related to science and technology, national norms expend more effort than high-achieving engineering students in terms of their library experience. An explanation of less effort by high-achieving engineering students in library experience may be due to the increased usage of the Internet, which enables students to access academic materials without necessarily visiting the library. Moreover, other campus facilities, such as dorms, computer labs, academic support centers, research labs, etc., might be more appealing to high-achieving engineering students than using the library space. Perhaps they prefer to work more independently in their private room [17, 51].

Evaluating the perception of high-achieving engineering students in terms of their college environment indicates that they and the national norm students have the same perception of their college environment. The college environment factors considered include scholarly emphasis, vocational and practical skill emphasis, and quality of relationships experienced in the environment.

Investigating the progress made towards the desired outcomes of college, high-achieving engineering students differ from the national norm in their intellectual and scholarly development. These findings corroborate the findings of other researchers [52]. The two groups also differ in terms of gains in science and technology, general education, workforce preparedness, and capacity for lifelong learning. On gains in personal development, high-achieving engineering students and the national norm are the same. The effect size computation shows that the difference between both groups is large regarding intellectual gains, scientific and quantitative gains, workforce preparedness, and capacity for lifelong learning. Effect size calculation shows that the difference in personal development is small. Effect size calculation also shows moderate differences in general education knowledge gains.

4.2 Recommendation

Based on the research findings of the present study, it is recommended that college administrators consider reducing tuition and providing more scholarships and on-campus jobs for students. Reduced tuition and scholarships help reduce the financial burden that forces students to sacrifice their study time for work. On-campus jobs allow students to better balance their time between study and work. For example, if faculty provide on-campus, paid undergraduate teaching and research assistantships to students, students' educational outcome gains will be improved. On the other hand, students should also learn effective time management strategies. Workshops on time management should be organized for students to improve students' time management skills [53]. Students are also encouraged to work with their faculty advisors or academic counselors to optimize course load and time spent working each semester. Faculty are encouraged to use evidence-based pedagogical strategies to increase students' engagement in academic activities. In short, administrators, faculty, and staff should work together to cultivate a positive and welcoming environment for all students.

4.3 The Limitations of this Study

This study has two primary limitations. First, the same size (n = 51) is moderate. Second, the study compared high-achieving engineering students at only one higher education institution with the national norm. It should also be noted that the data analysis and associated conclusions made in the present study are all based on the data generated from participants' self-report surveys.

Despite the above limitations, this study provides valuable information on what constructs high-achieving engineering students that significantly differ from the national norm. Such information encourages students to seek balance in their study-work life and invest quality effort toward academic activities to maximize their learning outcomes. The research findings of this study help college administrators and instructors develop policies and design an environment that can further enhance the college experience of high-achieving engineering students. Moreover, the research findings of this study suggest that average students can improve their college experiences by learning from their high-achieving peers. Instructors can also consider evidence-based pedagogical strategies that have been proven to increase students' engagement in academic activities.

5. Conclusions

Students' college experience and involvement in academic and non-academic activities play a significant role in affecting students' educational outcomes. Most existing studies on college students' experience focus on all students rather than high-achieving college students, especially high-achieving engineering students. The present study fills this research gap by performing quantitative research involving descriptive analysis, an independent t-test, and effect size computation for high-achieving engineering students at a public higher education institution in the United States.

The following paragraph summarizes the major research findings from the present study:

1. In terms of quality of effort, high-achieving engineering students invest significantly more effort in scientific and quantitative experience than the national norm. However, the national norm expends more effort in terms of their writing experience, the use of the library, and student acquaintances. Both groups are the same on all other quality of effort scales.
2. High-achieving engineering students spend more time on academic activities than the national norm.
3. The perception of high-achieving engineering students of their college environment is the same as that of the national norm.
4. Compared to the national norm, high-achieving engineering students make more significant progress toward the desired outcomes of college in terms of scholarly and intellectual development, scientific and technological development, gains in workforce preparedness, gains in intellectual skills, and capacity for lifelong learning. The national norm makes more significant progress than high-achieving engineering students in terms of gains in general education knowledge.

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Ning Fang is Professor and Department Head of the Department of Engineering Education at Utah State University, U.S.A. He has taught a variety of courses at both graduate and undergraduate levels, such as Engineering Dynamics, metal machining, and design for manufacturing. His research in engineering education is in broad areas of engineering learning & problem solving, technology-enhanced learning, and K-12 STEM education. His research in engineering focuses on the modeling and optimization of metal machining processes. He earned his PhD, MS, and BS degrees in mechanical engineering.

Ibukun Osunbunmi is Assistant Research Professor and Assessment and Instructional Specialist at Pennsylvania State University. He holds a PhD degree in Engineering Education from Utah State University. He also has BS and MS degrees in Mechanical Engineering. His research interests include student engagement, design thinking, learning environment, evidence-based pedagogy, e-learning, broadening participation in STEM education, sustainable energy, and material characterization. The work presented in this paper was conducted while he was a PhD student at Utah State University.