Assessing Awareness level of Engineering Graduate Students about Innovation Commercialization at Historically Black Colleges and Universities

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Sampson Addo is currently a Ph.D. student in the computer science and engineering program at the University of the District of Columbia and his research focus is promoting the commercialization of research innovations in Historically Black Colleges and Universities (HBCUs). His first degree is in Biology, and he has Masters in Agricultural Administration (with emphasis on project management). He is also working as the Grant Manager for Additive Manufacturing Post Processing Partnership (AMP3) in the Department of Mechanical Engineering (the University of the District of Columbia). He is very passionate about innovations and their impact on human life. His passion for the commercialization of innovations motivated him to develop a proposal with two of his colleagues (at the University of Ghana, Accra – Ghana) and was awarded $500,000 by the World Bank for the establishment of the Commercialization Center in the University. With the approval and support of the University leadership, he and his colleagues set up institutional structures, processes, and guidelines for the operations of the Center. Subsequently, a letter of commendation from the Vice-Chancellor (President) of the University, was given to him and his other two colleagues for this successful award.

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Abstract
Previous research attests to the fact that universities have unique strength that allows them to play a significant role in the process of innovation commercialization. Innovation commercialization seeks to transform products/services from the laboratory to the marketplace or the end-user. The number of commercialized innovations by Historically Black Colleges and Universities (HBCUs) – originally established mainly as teaching and blue-collar trade institutions to educate African Americans – is significantly lower than their non-HBCUs counterparts (specifically, Predominately White Institutions – PWIs). This is largely because HBCUs have been traditionally under-served and under-resourced. To bridge this gap, HBCUs are promoting entrepreneurial training and mindset through changes in engineering education programs and curriculum. For instance, federally funded programs like the National Science Foundation (NSF) Center of Research Excellence in Science and Technology (CREST) and NSF I-Corps promote the education and training of innovators on commercialization of innovations at HBCUs. Little Research has been done to investigate the level of awareness of engineering graduate students at an HBCU. The purpose of this study is to assess the level of awareness of engineering graduate students at an HBCU about innovation commercialization.

In this study, we conducted a survey using a questionnaire-based data collection method that focused only on engineering graduate students at the University of the District of Columbia. We used both binary and ordinal scales, where we ask questions first using a binary scale, such that If an answer is “Yes” then we follow it with another question using an ordinal scale that is whether awareness level is low, average, or high. The study population of interest includes 15 engineering graduate students at the institution.

The results from this study have been analyzed using participants' responses to the questionnaire and aggregating these responses to identify patterns. The results showed general low level of awareness and understanding of innovation commercialization processes. These patterns will be discussed in detail to illuminate the level of awareness about innovation commercialization in HBCUs. We are using the results of this study to provide useful guidelines and framework for HBCUs leadership to initiate programs to promote innovation commercialization, especially for engineering innovators. We intend to conduct further surveys in another study to cover engineering undergraduate students and subsequently faculty and administrative staff of an HBCU, to assess their level of awareness of innovation commercialization.

Keywords: innovation commercialization, engineering student, engineering education, Historically Black Colleges and Universities (HBCUs).
Introduction
The Higher Education Act of 1965, as amended, defines Historical Black Colleges and Universities (HBCUs) as: “…any historically black college or university that was established prior to 1964, whose principal mission was, and is, the education of black Americans, and that is accredited by a nationally recognized accrediting agency or association determined by the Secretary [of Education] to be a reliable authority as to the quality of training offered or is, according to such an agency or association, making reasonable progress toward accreditation.” [1]. They were established before 1964 expressly to educate African – Americans [2]. Since their establishment, their positive economic impact cannot be overemphasized as a study commissioned by United Negro College Fund (UNCF) makes it clear that their benefits also flow to the local and regional economies that are connected to HBCUs. Key findings from the study (based on 2014 data) include a total economic impact of $14.8 billion for their local and regional economies, a total employment impact of 134,090 jobs, and total lifetime earnings for graduates of $130 billion [3].

Though expressly established as teaching institutions to educate people of African American descent, HBCUs over the years have been providing all students regardless of background, race, ethnicity, a competitive way to develop their careers honing their innate talents and skills. They have also diversified into cutting-edge research areas of national and global importance, such as advanced manufacturing technology, biotechnology and biosciences, computer and computational sciences, defense and national security, energy, materials science and advanced materials, nanotechnology, neuroscience, and pharmacology [4], to mention a few.

Previous research indicates that with all these positive impacts, HBCUs are behind their non-HBCUs counterparts in innovation commercialization (IC) because historically they have been under-served and were originally established largely as teaching and blue-collar trade institutions [5]. To bridge this gap, HBCUs are promoting entrepreneurial training and mindset through changes in engineering education programs and curriculum. For instance, federally funded programs like the National Science Foundation (NSF) Center of Research Excellence in Science and Technology (CREST) and NSF I-Corps promote the education and training of innovators on commercialization of innovations at HBCUs [6], [7]. The I-Corps program has promoted innovation commercialization by educating faculty members and students in innovation commercialization using the customer discovery process [8], [9]. However, little research has been done to investigate the level of awareness of engineering graduate students about innovation commercialization at an HBCU. The purpose of this study is to assess the level of awareness of engineering graduate students at an HBCU about innovation commercialization. We strongly believe that supporting the commercialization of innovations in HBCUs will likely enable HBCUs to grow into new or stronger research-oriented institutions and ultimately have greater economic, employment, and lifetime impact.

Innovation commercialization/Entrepreneurship and engineering education
Innovation commercialization seeks to transform products/services from the laboratory to the marketplace or the end-user. Pyynönen et al, see innovation commercialization as a process that aims to create and implement a feasible business model for an innovation-based product-service system in the surrounding business ecosystem [11]. Universities have unique strength that allows them to play a significant role in the process of innovation commercialization. The key in this
transformation processes for product and services by universities is the training of researchers, faculty, and students to have entrepreneurial mindset to take products from their laboratory to the marketplace or the end-user for societal benefits. Engineering students, especially those in HBCUs, should be made aware through their educational system available opportunities for innovation commercialization and entrepreneurship training programs, such as the NSF I-Corps Program [12]. This will aid in developing an entrepreneurial culture at the student level within the institution that will encourage and promote innovation commercialization for societal benefit.

Study Design
The goal of this study is to conduct a pilot survey using a questionnaire-based data collection method that focused only on engineering graduate students at the University of the District of Columbia to assess their level of awareness about innovation commercialization. To achieve this goal, we adopted the following approach:

The HBCU and Target Group
The study was done in a public Historically Black College and University (HBCU) located in the eastern part of the US with two colleges and four schools, and an annual pre- COVID 19 enrollment of over 7000 students. It offers 81 undergraduate and graduate academic degree programs, with a strong ABET-accredited undergraduate engineering program. Within the school of engineering and applied sciences, it offers civil, mechanical, electrical, computer engineering, and computer science and information technology.

Our target group for this study is fifteen (15) graduate students in the school of engineering and applied sciences at the masters or doctoral level to assess their level of awareness of innovation commercialization in this university. The target group are from the mechanical, civil, electrical and computer engineering, and computer science and information technology departments. Most of them had attended this same HBCU for their undergraduate education. This group were selected as they are expected to be more interested in and aware of innovation commercialization, having at least completed their undergraduate program. Also, these are research-oriented graduate programs (both masters and doctoral levels), and students are all involved in conducting research, and as such are expected to generate patentable, transferable, and commercial innovations from their research projects. The background of the 15 engineering graduate students who responded in the survey are presented on table 1 below.

Table 1: Background Information of Target Group

<table>
<thead>
<tr>
<th>Description</th>
<th>Respondent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>60.0</td>
</tr>
<tr>
<td>Female</td>
<td>33.3</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Academic level</strong></td>
<td></td>
</tr>
<tr>
<td>Masters</td>
<td>46.7</td>
</tr>
<tr>
<td>Doctoral</td>
<td>53.3</td>
</tr>
<tr>
<td><strong>Undergraduate major courses studied</strong></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Develop survey for collecting Data

Based on our goal of assessing the level of awareness of engineering graduate students about innovation commercialization, we developed our survey instrument to be simple with 14 main questions. We used both binary and ordinal scales, where we ask questions first using a binary scale, such that If an answer is “Yes” then we follow it with another question using an ordinal scale that is whether awareness level is low, average, or high. An example of the binary scale question we used is “are you aware of the process to get your innovation commercialized in your university? (Responds: Yes/No),” followed by an ordinal scale question – “if yes, what is your level of awareness of the process for innovation commercialization in your university? (Responds: low, average, high). They were also asked if they are planning to commercialize innovations from their current research work, key challenges to IC, and whether IC should be included in the engineering curriculum at the graduate level. In the Appendix A, we present the 14 main questions and their sub-questions with their multiple answers.

Data Collection and Analysis

The survey was developed and distributed through the google form online survey tool link. It was initially distributed to over 30 engineering graduate students, however, fifteen (15) students responded fully to the survey questions. We calculated the percentages of the responses for each question (both binary and ordinal scales). This was done to identify the prominent pattern in responds to the level of awareness of engineering graduate students about innovation commercialization in their university.

Results and Discussions

The results from this study have been analyzed using participants' responses to the questionnaire and aggregating these responses to identify patterns. We present the results of the responses of students related to;

- entrepreneurship education in engineering at their undergraduate and graduate levels,
- opportunities in commercializing innovations,
- processes to get innovation commercialized,
- knowledge about internal and external innovation commercialization programs,
- key challenges to commercializing innovation, and
- inclusion of innovation commercialization in engineering curriculum at the graduate level.
Entrepreneurship education in engineering at their undergraduate and graduate levels

The graduate engineering students who participated in the survey were asked if they were taught entrepreneurship in engineering at their undergraduate degree level. Most of the students (that is 73%) responded that they were not taught entrepreneurship in engineering at the undergraduate level as shown in figure 1 and 80% at the graduate level as seen in figure 2. On the other hand, only four (4) students responded that they were taught entrepreneurship in engineering at the undergraduate level and three (3) at the graduate level. All those who said they were taught entrepreneurship at the undergraduate and graduate levels indicated low level of awareness. Which may indicate a low level of appreciation, understanding or awareness of entrepreneurial experience and competencies required to initiate commercialization of innovation.

The 15 participating graduate engineering students were asked if they have been taught entrepreneurship in engineering at the graduate level. Eighty percent (80%) responded that they have not been taught entrepreneurship in engineering as presented in Figure 1. Only 20% responded that they have been taught entrepreneurship in engineering and of this 50% indicated that their level of awareness is low while the other 50% indicated high level of awareness. This may indicate that most of the students who were not taught entrepreneurship at the undergraduate level have also not been taught in their graduate level. Hence, their low level of appreciation and awareness of entrepreneurship started from their undergraduate program and still persist in their graduate level.

**Opportunities in Commercializing Innovations in your University**

![Figure 1: Entrepreneurship at the undergraduate and graduate levels](image1)

![Figure 2: Opportunities in commercializing innovations and level of awareness of opportunities](image2)
From figure 2 above, 60% responded that they have heard or made aware of opportunities in commercializing innovation in this institution, while 40% said they are not aware. Out of the 60% who are aware, 67% indicated low awareness level, 22% average and 11% high level of awareness. This shows that though most of the students (60%) were aware of the opportunities in commercializing innovation in their institution, many in this group (>60%) have low level of awareness.

**Process To Get Innovation Commercialized**

Many of the students interviewed (87%) said they were not aware of the process to get their innovation commercialized, as presented in figure 3. Those who said they are aware were just 13% and out of this, 50% indicated low level of awareness and the other half indicated average level of awareness. This indicates that students may generally not be aware of the process for the commercialization of innovations in their institution.

![Figure 3: Process of innovation](image)

**Knowledge About Internal and External Innovation Commercialization Programs**

Almost all the students (93%) indicated that they are not aware of either internal or external innovation commercialization programs (as shown in figure 4). Only one participant who was aware of such programs, also had low level of awareness. This may indicate that students in general have not been exposed (via reading, announcement, promotion, teaching, etc.) to innovation commercialization programs that are taking place within and/or outside their institution.

![Figure 4: Knowledge about internal/external IC](image)
Key Challenges to Commercializing Innovation
We present a summary of what participants indicated are the key challenges to commercializing innovation in their institution below:

- innovation commercialization is not taught in either undergraduate or graduate programs
- inadequate information on the innovation commercialization process in their institution – no institutional structure to refer to for resources on IC
- lack of resources (human, technical, financial, business environment) to plan and manage the commercialization process
- the institution did not have a patent office until recently – students believe the office should organize seminars to educate them on the patenting process, and
- little or no research and development support for students.

Inclusion of Innovation Commercialization in Engineering Curriculum at the Graduate Level
Most of the students (>90%) who participated in survey indicated that IC should be included in the engineering curriculum at the graduate level because of the following reasons:

- students do not only become innovators, but also become self-sufficient
- students also have good and creative designs/ideas and there should be a class to aid them in commercializing these designs/ideas
- an additional opportunity that students can take advantage of to make financial gains
- information on IC will let students be more confident to transform their ideas to tangible products/services
- commercializing innovation is the most effective way to see students’ invention reach the masses to achieve its intended societal benefits
- understanding the concept will create opportunities for creating engineering businesses by students, and
- students will gain access to the required information on IC.

Possible Strategies to adopt to address key challenges to Commercializing Innovation
Based on further studies conducted, we suggest that in addition to including IC in the engineering curriculum at the graduate level, the following strategies can be adopted by HBCUs to address challenges identified.

- Create and promote an internal culture/environment that foster and encourages the incubation of ideas and transformation of these ideas into tangible products/services beneficial to society.
- Undertake rigorous publicity of IC processes, programs, and opportunities on campus through adverts, handouts, flyers, etc, to improve students’ understanding and awareness level.
- Promote IC by organizing training seminars/workshops led by experts from within the institution to focus on the process, programs, and opportunities in innovation commercialization.
- Establish a regular seminar/workshop and invite guest speakers from leading innovation commercialization institutions to share their experiences and lessons that they have learned over the years.
- Develop existing or/and create new collaborations with industry through education, research, and internship activities, to focus on aiding students to find and develop products/services to address a direct industry need.
Incentivize engineering students, faculty, and staff who transform ideas/innovations to marketable products/services.

Implications for Engineering Education Research and Practice
The results from this study have implications for engineering education research and practice. For engineering education research, we strongly believe that to fully authenticate and validate these findings additional study with many participants should be done, as this study population sample was small. These participants/students should cover those in both undergraduate and graduate levels. Also, this study should be done in other HBCUs to gauge the level of awareness about innovation commercialization for informed decision-making.

In terms of engineering education practice, we are of the view that based on our findings and validated findings from a larger study will help firm up our recommendation that entrepreneurship in engineering and innovation commercialization should be included in the graduate level engineering curriculum to assist in increasing awareness and understanding of the innovation commercialization process.

Conclusions and Future Work
In this study we set out to assess the level of awareness of engineering graduate students about innovation commercialization in an HBCU. Our findings from the analysis of responses from participants of the study, indicate low level of awareness and understanding of innovation commercialization as a concept and its processes.

Based on the smaller sample size who participated in this study from one HBCU, we believe that future studies should be a large study involving both undergraduates and graduates from different HBCUs. In such a large study, it will be essential to include demographical data in the survey.

To conclude, we recommend that HBCUs leadership may initiate programs within their institutions targeted at promoting the culture of innovation commercialization both at the undergraduate and graduate levels, if not yet available. These may include adding entrepreneurship and innovation commercialization to engineering curriculum, setting up technology transfer (innovation commercialization) offices to guide students/faculty about IC, organizing training programs to promote innovation commercialization, and inviting innovation commercialization experts as guest speakers for seminars. Additionally, the NSF I-Corps program is generally available and run by other HBCUs, as such we recommend that this program could be widely advertised for engineering students (especially through the school of engineering and applied sciences notice boards – physically and virtually) to participate.

We see this study as a pilot to conduct further surveys in another research to cover larger numbers of engineering undergraduate and graduate students, and subsequently faculty and administrative staff of an HBCU, to assess their level of awareness and appreciation of innovation commercialization. We also intend to conduct this study in other regional HBCUs within proximity of this current study.
Acknowledgment
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References
Appendix A

Innovation commercialization survey
The study is to assess the level of awareness of engineering graduate students at an HBCU about innovation commercialization. You hereby formally consent to participate in this survey as you finish and submit the survey. Thank you. Please respond to these questions provided below. Note that this survey will be aggregately analyzed, and your responses are done anonymously, so your confidentiality is assured.

Background Information
- Gender:
- Name of your college/University:
- Academic Level: Masters / PhD:
- Undergraduate/Masters major area of study: Mechanical, Civil, Electrical and computer engineering, Biomedical, Computer Science and information technology, other - specify
- Name of Undergraduate/Masters College/University (if different from current college/University:
- Current major area of study: Mechanical, Civil, Electrical and computer engineering, Biomedical, Computer Science and information technology, other - specify

Please answer the following questions:
1. As part of your undergraduate degree course, were you taught entrepreneurship in engineering? (Yes / No)
2. As part of your graduate degree program, have you been taught entrepreneurship in engineering? (Yes / No)
   2a. If yes, what is your level of awareness of entrepreneurship in engineering? (low, average, high)
   2b. If no, continue to question 3
3. Are you aware of the commercialization (technology transfer) of engineering innovations since you joined your university? (Yes / No)
   3a. If yes, what is your level of awareness of commercialization of engineering innovations? (low, average, high)
   3b. If no, go to question 4
4. Have you heard of or made aware of opportunities in commercializing innovations in your university? (Yes / No)
   4a. If yes, what is your level of awareness of opportunities in commercializing innovations in engineering? (low, average, high)
   4b. If no, continue to question 5
5. Are you aware of the process to get your innovation commercialized in your university? (Yes / No)
   5a. If yes, what is your level of awareness of the process for innovation commercialization in your university? (low, average, high)
   5b. If no, continue to question 6
6. Are you aware of the process for patenting innovations in your university? (Yes / No)
6. If yes, what is your level of awareness of the process for patenting innovations in your university? (low, average, high)
6b. If no, continue to question 7

7. Do you know of the different pathways/approaches for commercializing innovations? (Yes / No)
   7a. If yes, what is your level of awareness of the different pathways/approaches for commercializing innovations? (low, average, high)
   7b. If no, continue to question 8

8. Do you know customer discovery process (CPD) as part of innovation commercialization? (Yes / No)
   8a. If yes, what is your level of awareness of the customer discovery process? (low, average, high)
   8b. If no, go to question 9a

9. Are you aware of any innovations commercialization program(s) within or outside your university?
   9b. If yes, what is your level of awareness of innovations commercialization programs within or outside your university.

10. Are you aware of the National Science Foundation’s (NSF) I-Corps Program for commercialization of innovations?
    10b. If yes, what is your level of awareness of the National Science Foundation’s I-Corps Program? (low, average, high)
    10b. If no, go to question 11a

11. Are you planning to commercialize any of your graduate research work?
    11a. If yes, what innovation commercialization pathway/approach are you planning to adopt?
    11b. If no, go to question 12

12. In your opinion, what are the key challenges to commercializing innovations in your university?

13. Do you agree that innovation commercialization should be included in the engineering curriculum and taught at the graduate level? (Yes / No)

14. Please tell us your experience relating to responding to these questions (For survey improvement purposes).