From Undergraduate (Software) Capstone Projects to Start-ups: Challenges and Opportunities in Higher Institutions of Learning

Daniel Ogenrwot*
Gulu University
Gulu, Uganda
d.ogenrwot@gu.ac.ug

Geoffrey Olok Tabo
Gulu University
Gulu, Uganda
g.tabo@gu.ac.ug

Kevin Aber
Gulu University
Gulu, Uganda
k.aber@gu.ac.ug

Joyce Nakatumba-Nabende
Makerere University
Kampala, Uganda
joyce.nabende@mak.ac.ug

ABSTRACT

The capstone project is a fundamental part of almost all science and engineering degrees. It is not only a requirement for the partial fulfillment of an accredited university programme but also a method of assessing the students' general mastery of concepts, critical thinking, problem-solving, and transferable skills. Annually, final-year undergraduate students offering computing programmes in Uganda build innovative software solutions to real-world problems within and outside their community. Anecdotal evidence indicates that most of those innovations have the potential for commercialization and transformation into technology-based businesses. However, limited progress has been made to commercialize students' projects, and promising solutions are "buried" within academic reports. To this end, our research aims to explain the challenges and opportunities in the commercialization of students' capstone projects across two (2) undergraduate computing programmes (Bachelor of Science in Computer Science and Bachelor of Information Technology) offered at Gulu University in Uganda. Using exploratory research design, we reviewed eighty-six (86) capstone projects, curricula, and a facilitated students & stakeholders' workshop report. This paper articulates factors hindering the commercialization of undergraduate software capstone projects and recommends mitigating measures. It also proposes a framework for extending capstone course design from a traditional curriculum structure to an inclusive industry and community-oriented approach capable of turning ideas into business start-ups. The findings from this research are expected to inform higher institutions of learning in Africa in developing novel pedagogical approaches for orchestrating (software) capstone project courses that are inclusive and profitable beyond the academic setting.

*Corresponding author

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CCS CONCEPTS

• **Software and its engineering → Software creation and management**.

KEYWORDS

Software Engineering, Capstone Projects, Start-ups, Commercialization

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1 INTRODUCTION

The capstone project in Higher Education Institutions (HEIs) is an essential component of any accredited computing discipline such as computer science, software engineering, information technology, information systems, and computer engineering, among others. Since the publication of Software Engineering 2004: Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering (SE2004) [2, 20], capstone courses have gained more relevance, especially in software engineering education [3]. The structure of the capstone project varies from one institution and one computing programme to another. For instance, an institution might require students to work as a group while others require students to work individually on their capstone projects [16]. The structure is conceptualized based on the number of staff, students and the programme in the department. However, the ultimate goal is to provide students with the opportunity to demonstrate knowledge, skills, individual creativity, and originality. This also enables students to recognize and appreciate the complexity of software development and learn teamwork [8]. Logically, students apply knowledge and skills acquired throughout the computing programme and demonstrate investigative, problem-solving, and other transferable skills through building solutions to real-world problems. These solutions have lately targeted community challenges across various domains such as health, agriculture, education, smart home, and finance.

The capstone courses in most HEIs promotes students' team projects, capstone projects, and internship as a springboard for

developing innovative computing solutions addressing community challenges. In the case of developing countries, innovation is believed to be an enabler of sustainable development [7, 24, 28]. For instance, Uganda's Third National Development Plan (NDPIII) envisages innovation as a driving force to alleviate poverty [26] leading to social-economic development and economic growth. Therefore, we view capstone projects as a nexus of technology innovations with the potential to create new employment opportunities through start-up companies for talented students. Annually, final-year undergraduate students offering computing programmes in Uganda build innovative software solutions to real-world problems within and outside their communities. Anecdotal evidence indicates that most of those innovations have the potential for commercialization and transformation into profitable tech businesses. However, limited success is observed in implementing and commercializing students' projects beyond the academic setting. As such, promising solutions are "buried" within academic reports - not mistaken that these students' projects aim to satisfy the requirement for the award of an undergraduate degree.

To this end, this research aims to understand the challenges and opportunities for commercialization of students' capstone projects from HEIs in Uganda across two (2) undergraduate computing programmes. The two programmes considered in this paper are: Bachelor of Science in Computer Science (BCS) and Bachelor of Information Technology (BIT), offered at Gulu University in Uganda. In this study, we seek to answer two essential research questions;

RQ1: What factors influence the commercialization of innovative undergraduate software capstone projects at universities?

RQ2: What opportunities can be realized from undergraduate software capstone projects?

By answering the research questions, this paper contributes to the debate on commercializing students' innovative solutions to community challenges in two folds: Firstly, it articulates factors hindering the commercialization of undergraduate software capstone projects and recommends mitigating measures. Secondly, it proposes a framework for extending capstone course design from a traditional curriculum structure to an inclusive industry-oriented approach to turning ideas into business start-ups.

The rest of the paper is organized as follows: Section 2 provides a deeper description of the capstone project, how it is designed and conducted with the university structure, how it relates to internship, and the business prospects associated. The research design, tools, and materials are described in Section 3. Section 4 and 5 presents the result and discussion as guided by the research questions respectively. In Section 6, we discuss the threat to the validity of this study. Finally, the conclusion and future work are presented in Section 7.

2 CAPSTONE PROJECT AND START-UP

In this section, the study provides a deep dive into the notion of capstone projects and start-ups. The goal is to describe the design of capstone project courses, students' team formation, and assessment methods embraced by different universities. The section goes ahead to establish some fundamental relationships between capstone projects and internships before concluding with the start-up potential of capstone projects.

2.1 Capstone Project Course Design

As previously mentioned, capstone courses are important for students to integrate and apply technical knowledge and skills acquired in previous courses to solve real-world problems. Capstone courses are usually conducted in the final year of the students' program and often span one to two semesters of an academic year [21]. The course design and implementation of the capstone project vary from one institution to another or even from one department to another within the same institution. For example, one institution can provide the capstone project's project choice and team formation. In contrast, other institutions allow students to choose their project of interest and form their teams [23]. Bosco et al. [6] argued that student-selected teams perform better than random, instructor-selected ones.

Despite the variations in capstone project course design, the following activities summarize the baseline tasks of capstone project course at the undergraduate level;

(1) Identification of the problem and writing a concept note.
(2) Presentation and approval of concept note by the assigned supervisor.
(3) Preparation and presentation of the proposal.
(4) Development of solutions.
(5) Writing project report.
(6) Final project presentation and submission of the report.

Formally, IT2008 provides the following guidelines relative to IT capstone experiences [15, 21]: "The three common elements of nearly all capstone programs are: 1) students are divided into teams of typically 4 to 8 students each; 2) each team is given a real-world project or problem to solve; 3) this project takes many weeks to complete (typically 14 or more)". However, the above guideline slightly varies for most Universities in Africa. In the case of Uganda, students are divided into teams of not more than four members, and it is upon them to come up with exciting project ideas. A study by Hart and Polk [14] noted three significant factors that influence students' capstone project choices, i.e., (1) obtaining engineering experience in a particular field or technical area, (2) gaining exposure to a company for employment opportunities, and (3) working on a project sponsored by industry.

2.2 Capstone Project Presentation

Capstone project presentation is often the final task performed by the final year students of engineering and computing programmes. It allows students to demonstrate their final solution and explain its features and functionalities. The presentation usually takes 10 to 20 minutes, and another 10 minutes for questions and answers sessions to assess the students' understanding of the problem and solutions developed.

Presentation of capstone projects differs from product pitching because it often focuses more on academics and less on business orientation. Pitching allows students or innovators to demonstrate their ideas or solutions, leading to business start-ups. To affirm this claim, we show the most recent scoresheet for grading the capstone project from Gulu University in Appendix A.1. The grading domains are more inclined to research than the developed solutions' entrepreneurial values. This grading standard can create a bias in students' perception regarding the ultimate goal of the capstone

project. In turn, most students focus on fulfilling their academic requirements while ignoring the business opportunities of their developed solutions.

2.3 Internship and Capstone Project

In this sub-section, the paper describes the relevance of internship or industrial training as a supporting component for a successful capstone project.

Internships and capstone projects are widely used to integrate work-related learning in university curricula [17]. An internship is primarily designed to bridge the gap between theory and practice, which is the same as capstone projects. It gives meaning to everything a student has learned and makes practical sense to something they have known as theoretical [13, 25]. In software engineering and other computing domain, internship plays a significant role in building students' technical and professional skills required in the industry.

Jaime et al. [17] studied the effects of internships on developing subsequent computer science engineering capstone projects. The main hypothesis was that the completion of an internship will have positive effects on several aspects of the capstone projects: 1) improved student competencies; 2) improved capstone project outcomes; and 3) decreased supervision effort [17]. It was observed that internships before capstone projects improve student skills in technology, methodology, and project management; increase the complexity and technological novelty of the resulting projects.

Therefore, it is arguable that internships can provide an environment for students to develop novel academic and industry capstone projects. However, in Uganda and similar to the rest of (East) African countries, our experience indicates that Universities have not been working closely with industries and this is believed to limit the rate of commercialization of students' capstone projects.

2.4 Start-up Potential of Capstone Projects

As we discussed in previous sections, capstone computing projects can be observed as a nexus for technology innovation. The solutions developed over the years can be incubated into a business start-up.

However, past research on capstone design courses in engineering has focused on how to best structure the course to serve the educational needs of the students [4]. Limited work has been done to extend students' projects to potential business prospects.

According to Farahmand and Ely [12], restructuring the capstone project to align with entrepreneurial experiences is essential for students to learn how to transform their projects into a relevant startup venture or generate viable products for an existing organization. To achieve this goal, the traditional role of faculty advisors (supervisors) has to shift from a structured lecturer to a flexible facilitator, helping students to develop an idea into a functional & marketable product over one or two semesters. A study by Kulmala et al. [19] demonstrated how the capstone innovation projects were extended to capture "start-up" as the final stage of the projects. The main goal of their research was to discover new pedagogical models and methods for conducting capstone project courses. The target group was students of Bachelor of Information Technology at Turku University of Applied Sciences.

Overall, students' capstone projects have huge potential for commercialization but are not yet fully exploited by HEIs.

3 RESEARCH DESIGN

This research is inspired by students' capstone reports, a facilitated workshop involving students & stakeholders from the industry and over five years of the authors' experience in conducting capstone courses at Gulu University. We used an exploratory research design to understand the challenges and opportunities of commercialization of capstone projects. We used document review based on capstone projects reports compiled over the last four (4) years. Additionally, we studied capstone projects score sheets and existing curricula with a specific emphasis on capstone courses. We also draw on the workshop report conducted at the Department of Computer Science of Gulu University involving students and stakeholders representatives from the industry.

3.1 Document Review

The variety of documents from the university surrounding the development and assessment of capstone projects were reviewed. These documents include; (i) Students' capstone projects, (ii) Information Technology (IT) & Computer Science (CS) curriculum and (iii) Students & stakeholders engagement workshop report.

3.1.1 Students' Capstone Projects. A collection of students' capstone projects in the last four (4) years were evaluated based on the criteria guided by our research questions. The goal was to look into the capstone project direction and interest for the past four (4) years to inform our future engagement with students' projects and stakeholder needs.

Randomly sampled projects were followed up by calling the students on their cell phones to understand the status of their capstone project after completing the degree.

3.1.2 Curriculum. Two curricula for CS and IT programmes were reviewed with a specific focus on the intended outcome of the students' training and team projects. These curricula were accredited by the National Council for Higher Education (NCHE) in Uganda. NCHE is a body mandated by the government with the accreditation of degree programmes in Uganda.

The capstone and team project courses in the curricula are associated with a specific grading rubric aka score sheet (see Appendix A.2). We studied the score sheet to understand how the grading allocation supports or encourages the commercialization of students' capstone projects from the lens of entrepreneurship.

3.1.3 Students & Stakeholder Engagement Workshop. We analyzed students & stakeholder engagement reports from the workshop conducted in October 2021 to understand students & stakeholder perceptions of internships, incubation, and employability of undergraduates. The workshop comprised of students from the Department of Computer Science at Gulu University and stakeholders from the industry. The stakeholders emerged from various domains such as financial institutions, the hospitality industry, IT companies, start-ups, and others. Overall, the workshop was attended by 20 participants.

4 RESULT

This section presents results from the research activities we undertook in response to the research questions.

4.1 Students' Capstone Projects

In this process, we collected and reviewed eighty-six (86) capstone projects completed by students of the Department of Computer Science at Gulu University for the years 2018, 2019, 2020, and 2021. The capstone projects selection criteria were based on the availability of the final project report and the fact that the project was completed within the last four years. Some of the project reports are uploaded on the department's website[1].

Appendix A.1 provides a link to the table containing the list of reviewed projects. We intuitively developed a classification (taxonomy) of projects as observed in the category column of the table linked Appendix A.1. The taxonomy is based on the application area of the capstone project. As a result, fourteen (14) classes emerged, including; human resources, agriculture, business, office app, transport, government, health, education, finance, computer security, smart home, social, hospitality and entertainment. This classification aimed to understand the kind of project/innovation students tend to pursue to align students' interests with industry/other stakeholders' expectations.

Table 1 presents the summary and grouping of all the projects reviewed. It can be observed that students seem to often engage in projects related to education, agriculture, and health but rarely in computer security, office apps, entertainment and social-related projects. We also noticed a reduction in the total number of projects completed during the research selection period. This could be related to the widespread impact of COVID-19 on education.

Table 1: Categorization of the type of projects undertaken by students in the last four years.

Category	Year				Total
	2018	2019	2020	2021	
Agriculture	1	1	3	5	**10**
Business	2	2	0	2	**6**
Computer Security	1	0	0	0	**1**
Education	9	5	2	8	**24**
Finance	1	3	1	1	**6**
Government	3	0	1	0	**4**
Health	6	3	4	1	**14**
Hospitality	1	1	0	0	**2**
Human Resource	3	0	0	0	**3**
Office	1	0	0	0	**1**
Entertainment	0	2	0	0	**2**
Transport	3	0	2	2	7
Social	0	1	1	0	**2**
Smart Home	0	0	3	1	**4**
Total	**31**	**19**	**16**	**20**	**86**

Note: The highlighted cells represent the top three (3) categories.

[1] https://fos.gu.ac.ug/department/cs/?view=undergraduate-reports#

The "start-up" column in the table of reviewed projects (see Appendix A.1) indicates whether the project has made it to start-up or commercialization. Our finding shows that only 2 out of 86 of the reviewed students' projects over four (4) years have progressed to commercialization after completion from the university. These applications are developed and transitioned to commercial use. They are available on public App repositories (Google play store & Apple apps store) and web URLs for the case of web-based applications. Figure 1 is a pie-chart representing the ratio of commercialized and non-commercialized students' projects. The two projects in this case are; (i) Mwalimu Education Research (web[2] & mobile application[3]) and (ii) RideAlong App which now called SafariShare[4]

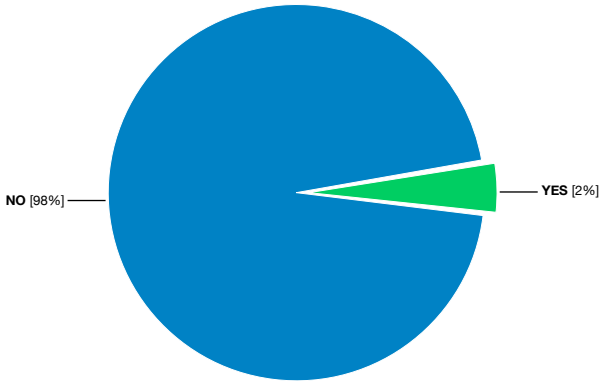

Figure 1: Percentage of commercialized and non-commercialized students' projects.

Findings

- Only 2 out of 86 (~2%) of the reviewed students' project have succeeded to commercialization over the last four (4) years.
- Education, Health and Agriculture are the top three (3) project areas undertaken by students.

4.2 Computing Curriculum

As previously mentioned, we reviewed the current CS & IT curricula at the department of Computer Science of Gulu University as accredited by NCHE. As observed in SE2004 [2], our findings indicate that both CS & IT programmes offer a course on capstone projects which is a four (4) credit unit (CU) course. The design and structure of its implementation follow the process as indicated in Figure 2. Essentially, the curricula focus heavily on academics and lack input from the industry. Furthermore, on the examination of the score sheet, we observed that only 2% of the overall score is awarded for the entrepreneurial value of the project. For further reference, the most recent score sheet used by the Department of Computer Science is included in Appendix A.2.

[2] https://mwalimu.ug/
[3] https://play.google.com/store/apps/details?id=mwalimu.ug.student
[4] https://play.google.com/store/apps/details?id=co.safarishare.app&hl=en&gl=US

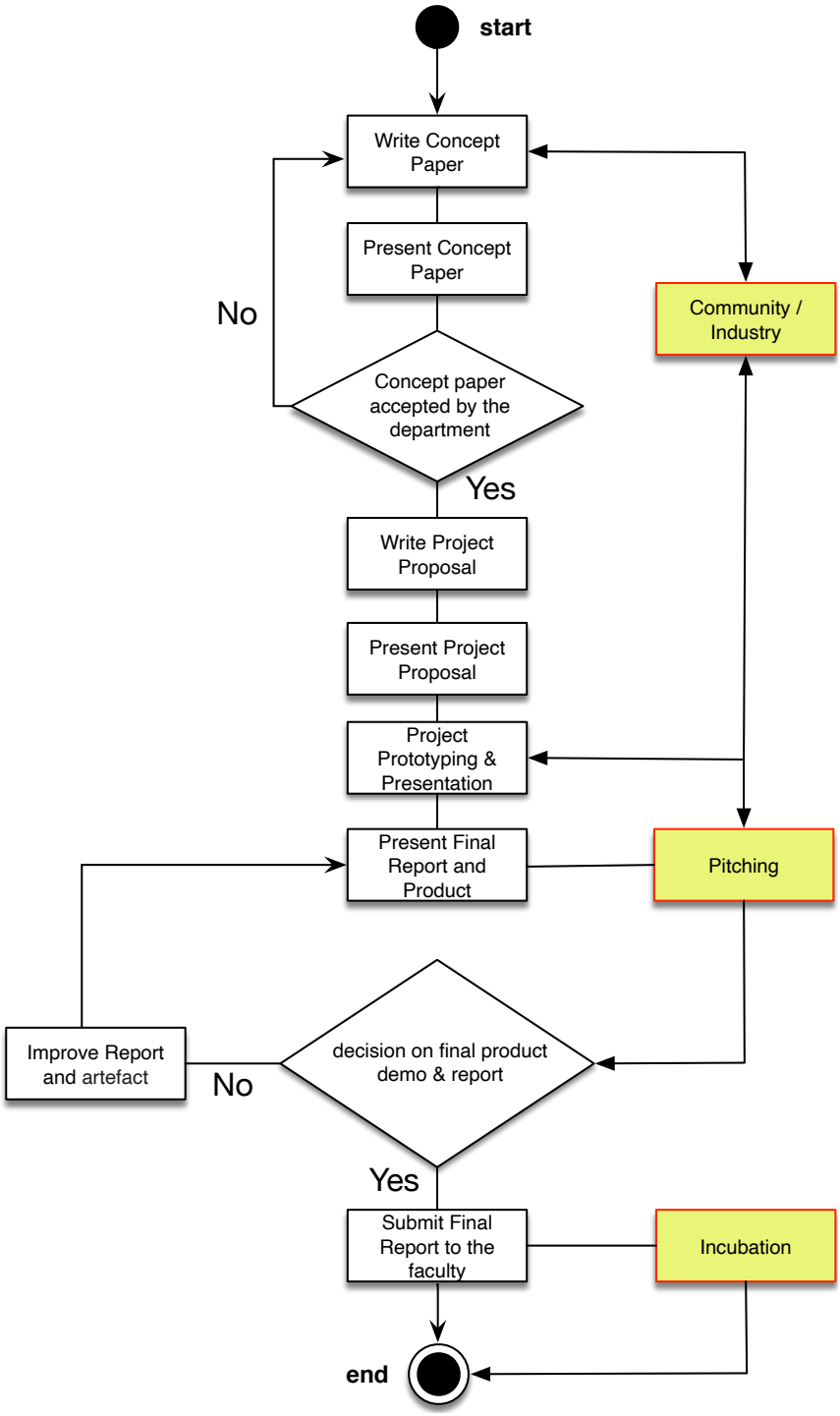

Figure 2: Flowchart showing baseline capstone project activities and proposed extensions in colored boxes.

Findings

- The curricula is skewed towards academic and lack input from industry or community.
- The score sheet awards only 2 out of 60% towards the entrepreneurial value of the capstone project.

4.3 Students & Stakeholders Engagement Workshop

The findings from the workshop indicated that industry participants were not satisfied with the level of practicals allotted to the training of IT & CS students. As cited by one of the stakeholders, "Students often fail to complete a practical task in the real world, especially in their first few months in the industry".

The workshop participants pointed out that there is an urgent need from HEIs to align the training of undergraduate (software) students to practice. Essentially, there is a need to balance theory with practice/fieldwork and problem identification with community or stakeholder needs. Additionally, they emphasized the need for students and faculty to focus research on contextual issues to address local challenges.

Findings

- Balance theory with practice and problem identification in relation to community or stakeholder needs.
- The need to focus research on contextual issues to address local challenges.

5 DISCUSSION

This section articulates the challenges and opportunities associated with commercialization of students' capstone projects based on the findings presented in the previous section. To better understand these challenges & opportunities, it is pertinent to understand the university "environment" where capstone projects are conducted.

5.1 The University Environment

The university is a higher education institution expected to expand education capabilities among students [5]. A student is admitted for a programme that can span a period of 2-5 years following a semester system and graduates after completion. The graduation requirements vary according to the programme and the institution. For the case of Science and Engineering (S&E), the capstone project is a fundamental requirement. In Uganda, all public and private universities offering S&E programmes engage students in a capstone project. The capstone course is usually part of the curriculum approved by NCHE and similar across all public and private universities in the country. Much as most universities in Europe and other parts of the world have adopted the practice of involving real clients from the industry in their capstone project courses [9], there is limited evidence of such practices in the (East) African context.

At Gulu University, the capstone project is integral to most S&E programmes such as Computer Science, IT, Bio-systems Engineering, Agriculture, and Physics. The capstone project is usually conducted during the final year of study, in a period of 1-2 semesters.

5.2 Challenges

5.2.1 Pedagogy. The curricula present a teacher-centered pedagogical approach with several limitations on students' creativity and innovation. The curricula offer a lot of theory with minimum hands-on for the artisans (engineering & computing students). This is a challenge to innovating capstone projects that can lead to start-ups since students have limited time to engage with stakeholders and current IT application development environments. Kuhrmann et al. [18] argue that HEIs have to educate the students to "learn how to learn" and are equipped with a profound basic and latest knowledge. Moreover, Bruegge et al. [8] observed that educating software engineering students to match real-world/industry jobs demands is challenging.

Therefore, we propose a more interactive pedagogy that addresses student-centred learning and presents a perfect fit between theory and practice. This could be through Problem/Project-Based Learning (PBL) or Competency-Based Education (CBE) for engineering and computer science programmes.

Similarly, the curricula design should emphasize appropriate coverage to develop the entrepreneurial skills of the learners and motivate them towards start-ups. In turn, it will reduce graduates' employability challenges leading to a more productive society. As observed in the result section, only 2% is awarded to the entrepreneurial value of the capstone projects at Gulu University. This allocation is relatively low and students could easily ignore the idea of scaling up their solution to profitable start-ups.

5.2.2 Students. The process of admitting students to HEIs is often based on their scores at high school, which is an examination that tests knowledge of the specific subject combinations offered. This kind of assessment is often brought into the university system by students working for higher grades instead of acquiring new skills, as is the case for university training.

Students need to engage with more real-life community challenges through PBL to develop their skills, attitude, knowledge, and competence to solve real-world contextual problems and prepare for employment opportunities. Such projects, curricula allowing, should be organized on a semester basis. As noticed from the workshop, most students lack technical competency in computer programming and essential soft skills such as presentation and communication even in their final year of study. Frequent engagement in solving real-life community challenges will improve their hard and soft skills and boost their self-esteem in handling IT projects.

Furthermore, students face challenges in understanding the problem they are trying to solve. Projects always emerge from the end-users where project requirements are comparatively easy to understand. However, most capstone project requirements are prepared based on students' assumptions, and experience, or by analyzing online materials or related documents. They fail to properly understand the project (goals, scope, stakeholder views, and the general requirements). Consequently, the solutions developed are not user-centered and fail user acceptance tests. As noted by Mao et al. [22],

involving users is essential for creating useful products and boosts the overall chance of its acceptance and usability.

5.2.3 IT Infrastructure. Much as this article raises concerns about the challenges and opportunities of commercialization of capstone projects, there is a significant problem with IT infrastructure in most (East) African universities to support students' innovative ideas. In a resource-constrained environment, Gulu University lacks supporting IT infrastructure to develop students' ideas and skills. These infrastructure challenges include but are not limited to; the high cost of internet and limited bandwidth, intermittent internet connectivity, expensive proprietary software licenses, IT hardware tools (e.g., Arduino toolkit, network equipment), and poorly-fledged laboratory. With such difficulty, the students tend to address academic requirements rather than an entrepreneurial goal regarding final year projects.

5.3 Opportunities

5.3.1 Contextual Solutions. Capstone projects promote local innovation and homegrown solutions. Developing countries usually depend on software solutions shipped from developed countries. These solutions are expensive and not designed for the local context. As such, customization is often required to meet the local needs. Both customization and maintenance costs are very high and not sustainable in the long run.

We argue that capstone project courses can be leveraged to encourage the design & development of contextual solutions which is highly maintainable and sustainable. In turn, this will encourage innovation and the creation of employment opportunities.

5.3.2 Employment. Capstone projects open opportunities that the employer world might not give. A capstone is a unit of study that allow students to apply their theoretical knowledge in a practical way that contributes to professional growth. It can foster employment twofold; (i) Skills acquired in the capstone project course accelerates undergraduate students' employability. Tech companies/industries are very competitive nowadays and rely on an individual's technical ability to complete a task. (ii) The notion of developing job creators rather than job seekers is vital in the fight against the high rate of unemployment.

5.3.3 Exposure. Exposing students to a real sense of purpose and direction as they carry out their capstone projects is essential. These spans technically but also socially and culturally. Apart from technical and educational knowledge, exposure allows students to learn numerous soft skills equally critical to the industry, such as collaboration, teamwork, ethical conduct, and cultural values.

5.3.4 Knowledge Diversification. Diversity in knowledge enhances soft skills such as communication and stakeholder management. Students can take a complex problem and present it in a way that everyday users can understand. Engaging in capstone projects widens students' knowledge from a specific domain (software) to other areas such as health, agriculture, transport, etc.

5.4 Capstone Projects to Start-ups

This section discusses three (3) key components we proposed as extensions to the existing capstone course activities illustrated in Figure 2. These components (partnerships, pitching & incubation) are believed to accelerate the transition of capstone projects to profitable start-ups.

5.4.1 Strategic Partnerships. Strategic partnership with stakeholders is essential in problem formulation in the context of the capstone projects and current challenges in the industry. The collaboration in this case, can start with the domains where most students are developing solutions based on our presented results.

As shown in Figure 2, we recommend University-Industry Collaboration (UIC) and University-Community Collaboration (UCC) at various stages of the capstone project course activities. Such collaboration will help students from the on-start of developing community/industry-targeted project ideas. The cooperation between universities and industries is observed as a vehicle to enhance innovation through knowledge exchange [1]. UIC & UCC will encourage user-centered design from concept development to prototype design, presentation and refinement. This will allow for the development of contextual solutions acceptable by the community and industry.

5.4.2 Pitching. The traditional approach of presenting a capstone report is mostly focused on the academic relevance of the solution and less on its entrepreneurial relevance. Moreover, such presentation is often conducted in isolation from the industry/community. This can be observed in the score sheet we reviewed (Appendix A.2). Drawing from the work of Faff [11], this paper recommends that HEIs should adopt pitching in collaboration with the industry/community (see Figure 2) to attract potential investors who can turn students' solutions into profitable start-up businesses. As noted by Drake [10], even a brilliant start-up business will not succeed if it cannot convince investors that its product or service is worth the investment. Engaging students in pitching strengthens their academic and business presentation skills which are essential for establishing a start-up.

5.4.3 Incubation. Following establishing strategic partnership and pitching, these capstone projects are only commercialised through technical and business incubation. Universities need to create these incubation centers as a base to launchpads for innovative and viable projects.

5.4.4 Leverage Internship. As previously discussed, an internship is pertinent for quality capstone projects. A study by Jaime et al. [17] observed that internship before the capstone project course increases the complexity & technological novelty of the capstone project. Therefore, this study argues that internships, if well exploited, can provide a convenient environment for students to identify realistic domain-specific project ideas emerging from the industry. These will allow for the design of highly acceptable and usable projects in a given domain.

6 THREATS TO VALIDITY

In section, we discuss internal and external validity of this research (according to Wohlin et al. [27]).

6.1 Internal Validity

The internal validity might be threatened by the documents, students and stakeholders selected in this study. We reviewed capstone project reports for the last four (4) years and conducted the workshop with only twenty (20) participants. We argue that this could have skewed our findings to the decision of the selected groups only. The research could benefit from a large number of participants and possibly a survey questionnaire to gain insights from a diverse group of participants.

6.2 External Validity

The external validity of this research might be affected by the small sample size of the documents reviewed and the research methods selected in the study. In addition, the research scope was limited to Gulu University and universities in Uganda. This could affect the ability to generalize our results. However, capstone courses are conducted in all HEIs and take a similar structure. Therefore, our findings can still be generalized to other HEIs.

7 CONCLUSION AND FUTURE WORK

The paper studies the challenges and opportunities of commercializing undergraduate (software) capstone projects in HEIs, with a special focus on universities. Based on an exploratory research approach, eighty-six (86) capstone projects, curricula and workshop report involving students and stakeholders were reviewed. This study explains the possibilities of harnessing students' capstone projects to generate business and employment opportunities for fresh graduates. Drawing from the research method, the study uncovered several factors limiting the transition of capstone projects to start-ups which are broadly grouped as (i) pedagogical, (ii) student factors and (iii) IT infrastructure issues.

We hope these findings can inform both students and HEIs in developing novel pedagogical approaches to conducting capstone project courses that are inclusive (in partnership with industry & community) and profitable (focus on entrepreneurship) beyond the traditional academic setting. HEIs should explore developing contextually relevant approaches to managing project courses, harnessing internships, and promoting student-centered learning and PBL, with close involvement of industry clients.

This paper provides a high-level understanding of the subject matter. Future work includes a more focused and detailed analysis of the impact of the capstone project course on students' software engineering skills. Essentially, we intend to address pedagogical challenges identified in this study by recommending a flexible curriculum design framework that addresses academic and entrepreneurial interests. Furthermore, it is still unclear how to determine the commercialization potential of capstone project ideas from the start of the project. It is essential to develop a standard metric/assessment criteria that can be used in HEIs to ascertain the commercialization potential of such a project.

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A APPENDIX

A.1 Capstone Projects Reviewed

The detailed description of the reviewed capstone projects is available in GitHub and accessible using this link: *https://github.com/Software-Capstone-Projects/famecse2022/blob/main/capstone_projects_list.pdf*

A.2 Capstone Presentation Score Sheet

GULU UNIVERSITY

P. O. Box 166, Gulu,
Email: headcs@gu.ac.ug

Tel: +256-4714-32106
Website: www.gu.ac.ug

DEPARTMENT OF COMPUTER SCIENCE
OFFICE OF THE HEAD OF DEPARTMENT

SCORE SHEET FOR FINAL YEAR PROJECT REPORT PRESENTATION (GCS 3201, DCS 2201) SEMESTER II 2020/2021
REPORT CONTENT AND PRESENTATION SKILLS

Group No: Project Title:

Reg. Number Name:
1.
2.
3.

Sections	Subsections	Benchmark Scores	Actual Scores		
Part I: Here all students are given the same mark for each scored section					
1.	Entrepreneurial Value of the Research	02			
2.	Problem Statement	02			
3.	"SMART" Objectives	03			
4.	Extensiveness and Appropriateness of Literature Review	03			
5.	Methodology	05			
6.	Product performance Demonstration	30			
7.	References	05			
Part II: Each student will be given a different mark according to h(is/her) performance					
	Student's List Number		1.	2.	3.
8.	Presentation Skills	10			
	Total Marks	**60**			

Name of Lecturer:

Signature: Date:

Figure 3: Final capstone project presentation score sheet for the department of Computer Science