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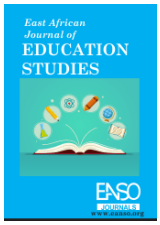

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Original Article

An Undergraduate Biosciences Internship Program in a Low-Resource Setting: Opportunities and Challenges.

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ABSTRACT

Makerere University institutionalised internship in 2011 with the goal of producing practically-oriented graduates meeting the job-related competences of their future employers. Using students' internship reports from 2011 to 2018, this paper examines whether undergraduate Biochemistry (Major) internship contributes to work-place readiness. Four categories of internship host organisations were identified: Industry, Clinical, Analytical and Research. Students were exposed to laboratory techniques in 6 major specialties: Molecular Biology, Immunology, Microbiology, Diagnostics, Chemistry and Physical-analytics. 48% of students reported additional experiences, the most common being data analysis, presentations and report writing. The benefits of internship reported include gaining new skills and/or knowledge, networking, and experience of a professional environment. Challenges included inadequate laboratory space, supplies, and limited safety gear. Notwithstanding the challenges of implementing an undergraduate biosciences internship program in a less-industrialised country context, students have relevant hands-on laboratory exposure and the opportunity to gain "employability skills" that enhance their work-place readiness.

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INTRODUCTION

Higher education plays a crucial role in development by generating human capital for key areas such as health, education, science, and technology thus building a country's capability for self-reliance. In low- and lower-middle income countries, higher education has been found to influence development through positive impacts on productivity in the workplace and on graduates' capabilities, as well as through macro-level economic growth and possibly through increased likelihood of technological uptake and adaptation (Oketch, McCowan, & Schendel, 2014; The Task Force on Higher Education and Society, 2000). For higher education institutions (HEIs) to contribute meaningfully to development, the quality of graduates and the extent to which their skills match the labour market is paramount (Pana & Mosora, 2013). Thus, curricula have to be relevant to the development needs of the country or region, the training approaches used should generate work-place ready graduates, and the gap between HEI *"Ivory Towers"* and their local partners should be bridged (Mugabi, 2015; The Task Force on Higher Education and Society, 2000; Thompson et al., 2018); this is the rationale behind student internships (field attachment, industrial training, practicum, work-integrated learning).

Internship was institutionalised at Makerere University (the oldest and largest University in Uganda), in 2011 with the core objective of producing practically-oriented graduates that meet the required job-related competences of their future employers, and to also serve as a linkage between the University and the partners who consume the services and/or products of the University (Makerere University, 2011). Evaluation of internship at Makerere has so far been limited to health professions programs and the agricultural sciences. In this paper, we address this gap for the BSc Biochemistry (Major) internship program by examining the students' internship reports from 2011 when the program was institutionalised, to 2018, in order to ascertain whether the overall purpose of providing real hands-on experience and contributing to work-place readiness is being achieved. We also document the students' broader learning experiences with the aim of informing review and improvement of the internship program. This paper first briefly reviews the importance of internship programmes for undergraduates from relevant literature. Next, the internship program at Makerere University is described, highlighting the BSc Biochemistry (Major) internship program, followed by a description of the current study and discussion of the findings, drawing attention to the students' experiences, and their perceptions of the benefits and challenges of internship.

UNDERGRADUATE INTERNSHIP

Internship is a field-based practical training during which students are placed at partner organisations to carry out purposeful, meaningful, hands-on

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activities that are relevant to the student, and it allows students to make connections between campus-based learning and the real world (Cheong, binti Yahya, Shen, & Yen, 2014; Renganathan, Bin Abdul Karim, & Li, 2012). Internships are an example of work-integrated learning (WIL) which is defined as an educational approach in which students spend time in professional, work, or other practice settings relevant to their degrees of study and to their occupational futures (Smith, 2012). These settings provide students the opportunity to gain relevant work-based experiences which allow them to integrate theory with the meaningful practice of work as an intentional component of the curriculum. Six core domains of WIL have been identified (Smith, 2012): (1) Authenticity, which requires that students engage in work-related tasks that are meaningful both to their academic study ('cognitive authenticity') and to the workplace; (2) Alignment of teaching and learning activities with integrative learning objectives; (3) Alignment of assessment with integrative learning objectives; (4) Integrated learning support from both the university and workplace sites; (5) Supervisor access and (6) Induction and preparation processes.

McCune (2009) and Bullock, Hejmadi, & Lock (2012) also use the terms "authentic learning experiences" and "authentic context" to describe the rich learning contexts of host organisations that provide realistic experiences of how scientists work. There is a variety of internship formats, but consistent across different approaches is that an internship involves placement of an enrolled student at a host organization for a minimum of 6-10 weeks and up to 1 year, with a faculty supervisor, a host organisation supervisor, and some academic credit earned toward their degree. The internship may be elective or mandatory and maybe paid or not; the 1-year internship is always paid. In some settings internship may be taken only by students who have achieved the required academic grade.

The benefits of internship across academic disciplines are well documented: internship nurtures individual abilities, skills, and interests; provides real hands-on experience; supports integration of theories learned in classroom with real life situations and fosters development of professional work habits, attitudes as well as networks (Cheong et al., 2014; Opolot, Isubikalu, Obaa, & Ebanyat, 2018; Renganathan et al., 2012). Internship has also been shown to have academic benefits for a range of disciplines (Binder, Baguley, Crook, & Miller, 2015; Jones, Green, & Higson, 2017) and it facilitates the acquisition of inter-personal, computer, communication and self-evaluation skills, which are considered "employability skills", that is, skills that enable an individual use the more specific knowledge and technical skills that their particular workplace requires (Lowden, Hall, Elliot, & Lewin, 2011; Mwanika et al., 2011; Washor, 2015). Internship has similar benefits for bioscience students: they gain practical laboratory-skills, employability skills and may also improve their academic performance (Bullock et al., 2012; Gomez, Lush, & Clements, 2004; Hejmadi, Bullock, Gould, & Lock, 2012). It is worth noting that the available literature on bioscience internships is largely from programs that have the 1-year placement.

For Biochemistry undergraduates, internship host organisations should ideally have well-equipped and functioning laboratories since Biochemists are trained for a variety of laboratory-based careers including medical, agricultural, pharmaceutical, and environmental research, industry, and academia (American Society for Biochemistry and Molecular Biology, 2016; Graduate Prospects Ltd, 2019; New Scientist, 2019). This however presents a challenge for Biochemistry internship programs in science and technology lagging countries like Uganda where research and laboratory infrastructure is inadequate and the level of industrialisation is low. To illustrate, Gross Domestic Expenditure on Research and Experimental Development (GERD), which is used to assess national scientific and technological strength, is 0.2% of GDP in Uganda, which is below the 1% target for African Union member countries (UNESCO Institute for Statistics, 2019). These statistics are supported by studies describing the inadequacies in research infrastructure for health (Kebede et al., 2014), including basic sciences (Elliott et al., 2015) and fields such as genomics (Adebamowo et al., 2018) and biotechnology (Chambers et al., 2014) which are at the cutting edge of applying technology for human development. Moreover, the number of bioscience programmes and students at Makerere University (The Visitation Committee on Makerere University, 2017) and in Uganda as a whole has grown rapidly

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(Tukacungurwa, Ssebbale, & Basiime, 2012) thus the competition for the limited suitable internship opportunities is high.

Institutional Context

Makerere University, the oldest and largest University in Uganda, was founded in 1922 as a Technical College and became a fully-fledged University in 1970 (https://www.mak.ac.ug/about-makerere/historical-background). Internship for undergraduates was approved by Senate, the University's highest academic body, in July 2006. Prior to this, the training existed for selected disciplines such as school practice for Education, community-based education and services for various health professions programs, and industrial training for some science and engineering programs. In addition, a few students on their own initiative made arrangements with organisations they were interested in and went for the equivalent of internship. Following institutionalisation across the University in 2011, the term "field attachment" was adopted for all teaching units to refer to *"any approved field-based practical work carried out by staff and students for the purpose of teaching and/or research in places outside the university control"* (Makerere University, 2011). Internship is implemented through a partnership of three key stake holders: the internship host organisations, the University (including academic supervisors) and the students.

Organization of Internship

Internship is organized through six steps: program management, budgeting, pre-placements, placements, supervision, and evaluation. Each of these processes is independent but ultimately contributes to the overall objective of internship.

Program management: This refers to the coordination and harmonization of internship activities, including reviewing the supervision, assessment, and final evaluation of internship. A subcommittee of Senate has overall oversight, while at the College level there is a committee comprised of Deans, Department Chairs and internship coordinators chaired by the Deputy Principal.

Budget: This is done to plan for students' maintenance, students' materials such as logbooks, and planning and preparation for students' placements and supervision.

Pre-placements: This consists of three key tasks: (a) Visits to and joint planning with internship host institutions by the internship coordinator with the aim of negotiating relationships, roles, and responsibilities. (b) Briefing the students, a week before placement in order for them to appreciate internship as an integral part of their training. The briefing covers the purpose of internship, basic requirements in terms of equipment and materials, code of conduct, roles of academic and field supervisors, evaluation and grading, various communication channels for students, the final internship report format, matters concerning their welfare, and health and safety issues. (c) Re-orientating the academic staff to ensure that the participating academic staff members appreciate the purpose of internship and the tasks involved, as well as developing and reviewing the monitoring tools, and evaluation/assessment criteria.

Placement: This process looks at three key tasks namely: (a) Duration and timing: the year of study the students go for internship depends on the design of the academic program. For most programs, internship takes place at the end of the fourth semester (at the end of the second year of study) for a period of eight weeks. (b) Posting: this includes identifying suitable candidates for each site, preparing letters of introduction and other necessary documents (i.e., guidelines for internship report writing, students evaluation forms, log books), and payment of students' internship logistical and financial support. (c) Students' records: During internship the students are required to keep logbooks as evidence of their daily activities as well as new knowledge and skills learnt. The on-site supervisor is expected to assess these daily records. The log books are also assessed and signed by the academic supervisor at each visit. Additionally, each student produces a final report detailing their internship experiences.

Supervision: The internship supervisors provide day-to-day supervision while the academic supervisor from the University is expected to visit the student at least three times. During the visit, the academic supervisor interacts with the student, the internship supervisor or other relevant officials and

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acquaints himself/herself with the student's activities as reported in the log book and the student's laboratory book as applicable.

Evaluation: As a core compulsory component of all undergraduate academic programs at Makerere University, internship is assessed and graded and contributes towards the student's final award with an overall weighting of 5.0 credit units.

The Biochemistry (Major) Program at Makerere

Biochemistry is a laboratory-based science discipline that explores the molecular basis of life. At Makerere University, the subject is taught at the College of Natural Sciences and the program sets out to: equip students with knowledge and skills in biochemistry; train biochemists that think independently but work collaboratively with others in the advancement of knowledge in biochemistry; provide the students with the skills of identifying and solving problems relevant to the needs of the country and encourage the students to identify community concerns related to biochemistry. Biochemistry majors are required to cover a total of 60 credit units in Biochemistry including the mandatory 8-10 weeks of field attachment at the end of second year, which contributes five credit units (BSc Biochemistry (Major). Biochemistry majors take a minor subject selected from Chemistry, Zoology, Botany, Mathematics, Computer Science or Geology. Internship follows the institutional processes described above, with the addition that students are given the opportunity to identify the internship host organisations they are interested in, and if deemed suitable, are approved to go to those organisations. Secondly, Biochemistry students are required to give an oral presentation of their internship, which is assessed and contributes to their overall internship grade (this is not a university-wide practice).

Although undergraduate internship was institutionalised in 2011 at Makerere University, only a few teaching units such as the College of Health Sciences (Atuyambe et al., 2016; Chang et al., 2011; Kaye et al., 2011; Kizito, Baingana, Mugagga, Akera, & Sewankambo, 2017; Mbalinda et al., 2011) and the School of Agricultural Sciences (Opolot et al., 2018) appear to have evaluated their internship programs. As reported by the Visitation Committee on Makerere University, (2017), there is little or no follow up on Internship [field attachment] Reports. This is the first time the internship component of a bioscience program of Makerere University, and to the best of our knowledge, in the country and region, has been examined. The aim of the study was to ascertain whether internship is achieving its overall purpose of providing real hands-on experience and contributing to work-place readiness in the context of inadequate scientific and technological capacity.

METHODS

All internship reports for BSc Biochemistry (Major) students for the years 2011 to 2018 (N=152; 32% female) were examined. A data extraction tool was developed based on the following themes which comprise the major sub-sections in the internship reports: internship host organisation, hands-on experience, other experiences, and the student's perspective regarding benefits and challenges of the internship. We randomly selected one report from each academic year to pre-test the data extraction tool. Thereafter, data was extracted from the reports after which the study team together reviewed the data extracted from each individual report for content in order to identify categories within each theme. Apart from internship organisation, it was possible for more than one category to be identified in a particular theme for an individual student. Data was summarised using frequencies and percentages and is presented for the whole sample as well as disaggregated by the year of internship and by internship organisation category.

RESULTS AND DISCUSSION

The categories that were identified within each theme and the respective definitions or descriptions are presented in *Table 1*.

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Table 1: Themes, categories, and category definitions.

Theme	Category	Definition/description
Internship organisation	Industry	For example, food, brewing, pharmaceutical
	Clinical	Clinical laboratories; public or private, health facility based or independent
	Analytical	Non-clinical analytical
	Research	Health/medical, agriculture and food research laboratories
Hands-on experience	Molecular biology	DNA and RNA assay techniques, mainly PCR based
	Immunology	ELISA, FACS, immunochemistry techniques
	Microbiology	Bacterial cultures and assays
	Diagnostics	Clinical diagnosis techniques including microscopy on blood smears, rapid diagnostic tests
	Chemistry	Determination of various compounds e.g., starch, thioglycolic acid, volatile fatty acids, fatty acid methyl esters, using chemical means
	Physical-analytics	Colour determination of beer, turbidimetry, determination of electrical conductivity and pH, determination of dry matter and brix
	Others-laboratory	Phlebotomy, phytochemistry, product development (bioplastics from plant materials)
Other experiences	Data analysis, presentations, report writing	
	Induction training, orientation	
	Special projects given to interns at some of the host institutions	
	Record keeping	Patient records, sample logs, stores
	Administration and Leadership	Leader of interns
Student's perspective of benefits	Networking	Exchange of knowledge and experience with students from other Universities; interacting with high profile individuals
	New skills and/or knowledge	Includes inter-personal, computer, communication, self-evaluation, and laboratory skills
	Exposure to professional environment	Proper code of conduct at work; understood workplace ethics
	Others	Hepatitis B, Yellow fever vaccinations; certificates (GCLP), training allowance given by some host organisations; awards - some host organisations have competitions (e.g., in presentations) and winners are awarded certificates
Student's perspective of challenges	Host: issues to do with access and supplies laboratories	Limited access to laboratories: some laboratories are restricted access, in other places it is due to many interns; they have to remain in the laboratory they are assigned. Faulty equipment, inadequate samples, reagents, and supplies. Inadequate laboratory space due to many interns.
	Host: Lab safety	Limited safety and protection gear, risk of exposure to infectious agents and hazardous chemicals; accidents
	Host: general organisational issues	Interruptions in supply of power and water, bench fees, closure of organisation, busy staff, time management
	University-related	Insufficient funding: transport, accommodation. Limited time for internship; poor communication between host and supervisor. Some host institutions have limited information about BSc. Biochemistry.

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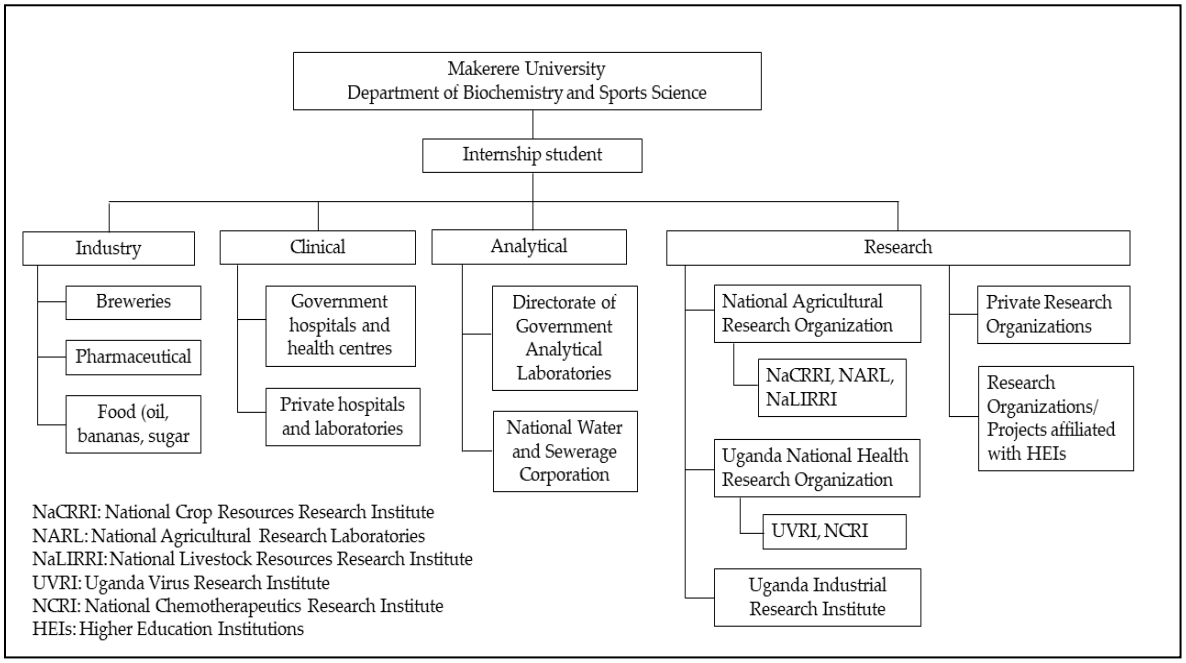
Theme	Category	Definition/description
	Others	Adapting to work environment; difficult working hours; reduced motivation for work; inadequate briefing and supervision; inadequate prior knowledge because some relevant topics are covered in third year

Internship Organisation

Characterization of the internship organisations based on their overall functions generated four categories of internship organisations as defined in *Table 1:* Industry, Clinical, Analytical, and Research. As *Figure 1* shows, compared to the other categories, research had a wider variety of sub-categories suggesting that there is greater diversity in the research space in Uganda for internship opportunities suitable for Biochemistry undergraduates.

Figure 1: Categories and sub-categories of internship placement organisations for Biochemistry (Major) students, Makerere University 2011-2018



It may also indicate that research organisations are more open and willing to take on internship students given that they are routinely involved in graduate research training. It is likely that students have a greater interest in the types of organisations that exist in the research space and are therefore opting for them over the other categories. This is supported by the finding that apart from 2011 when half the students went to clinical settings for internship, more students have gone to research organisations than any other type of organisation (*Figure 2)* giving an overall total of 77/152 (51%).

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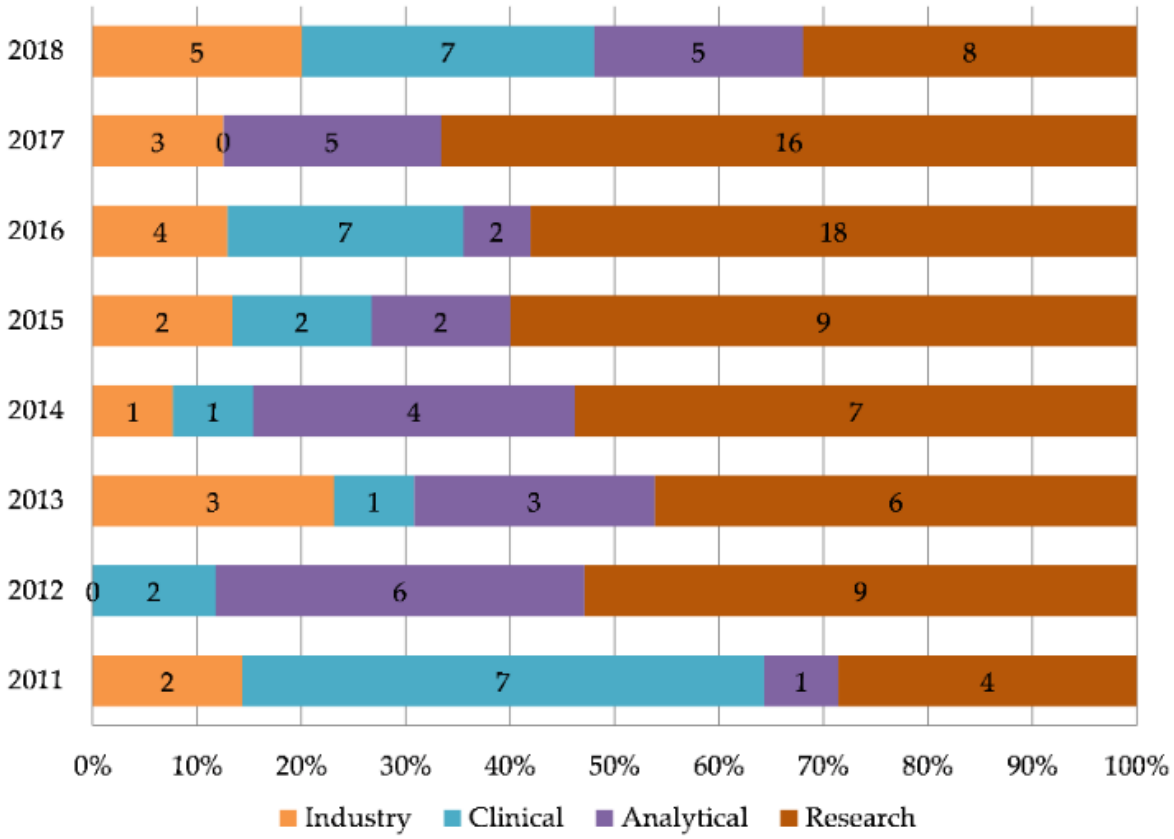
Figure 2: Distribution of Biochemistry (Major) students by category of internship organisation and year of study, College of Natural Sciences, Makerere University 2011-2018



Internship as a core course in the Biochemistry (Major) curriculum started in 2011 at which point funding modalities were not yet completely elaborated. Students were therefore advised to identify host organisations in their home areas to minimise costs. Accordingly, in 2011, 7 out of the 14 students did their internship up-country in locations at distances out of Kampala Capital City ranging from 66 km to 382 km (data not shown). Notably, five of the seven up-country internships were Clinical, and four of these were at public health facilities. Uganda has 14 regional referral hospitals and 139 general hospitals situated all over the country and all of them have laboratories (Ministry of Health, 2019). In contrast, internship organisations in the Research, Analytical, and Industry categories are not as widely distributed geographically. Clinical settings could therefore be seen as "low-hanging fruit" where a student can readily get a placement; indeed, it is noteworthy that again in 2011, 7 out of the 14 students did their internships with a clinical host organisation *(Figure 2).* Moreover, based on the laboratory test menus established by the National Health Laboratory Services, students would, in theory, get appropriate laboratory hands-on experience including haematology, parasitology, serology, and biochemistry at Health Centre IV (Health Sub-District) and at District and Regional Referral Hospitals (Uganda National Health Laboratory Services, 2017). In practice, however, not all the laboratories are at the same level of functionality. It would therefore be strategic to target the 100 laboratory "hubs" which form a network of referral laboratories covering the whole country (Ministry of Health, 2017). Additionally, the health units whose laboratories are supported through infrastructure improvement, provision of equipment, quality improvement, and human resource strengthening under the Strengthening Uganda's Systems for Treating Aids Nationally (SUSTAIN) project (University Research Co. LLC, 2019) could also be deliberately targeted.

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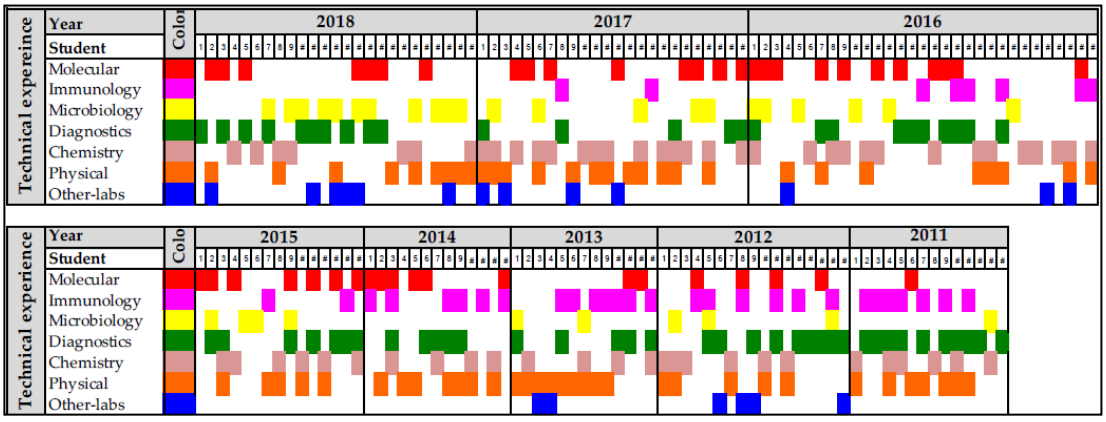
Hands-on Laboratory Experience

During internship, students were exposed to various laboratory techniques which were broadly categorised into six specialties *(Table 1)*, namely, Molecular Biology, Immunology, Microbiology, Diagnostics, Chemistry, and Physical Analytics. As *Figure 3a* shows, the majority of students got hands-on experience in at least two of the different laboratory technique specialties. A minority of students (33/152, 22%) were exposed to only one specialty; nevertheless, they were not necessarily at a disadvantage because any particular specialty includes several different laboratory techniques *(Table 1)*. The laboratory specialties that have remained consistent over the study period in terms of the percentage of students exposed include Chemistry, Physical-analytic, and Diagnostic techniques *(Figure 3b)*, which indicates a bias towards analytical chemistry techniques involving qualitative and quantitative assessment such as colour measurement and analysis (for example of water, beer, food products); turbidimetry; determination of electrical conductivity and pH; determination of biochemical and chemical oxygen demand; determination of dry matter and brix, and clinical-based techniques including disease diagnostic tests based on blood and urine assays; drug assays and blood typing.

A minority of students (19/152, 12.5%) had hands-on experience in phlebotomy - in the Clinical and Research categories; phytochemistry - in the Analytical category, and product development in the Research category; these were grouped together as 'Other laboratory'. The diversity of techniques revealed in the current study is not unexpected for biochemistry internships because of the wide application of biochemistry (American Society for Biochemistry and Molecular Biology, 2016; Graduate Prospects Ltd, 2019; New Scientist, 2019). Other authors have reported similar diversity in exposure to laboratory techniques (Bullock *et al.*, 2012; Gomez *et al.*, 2004). Naughton and Naughton (2016) caution that it is not feasible to closely match internships for different options in bioscience disciplines. Importantly, these findings indicate that internship is addressing the overall purpose of providing real hands-on experience. Additionally, the findings suggest that the learning contexts and experiences are authentic given that the tasks the students engage in are meaningful to their academic study being relevant to many of the courses in the curriculum (BSc Biochemistry (Major) and ostensibly contribute to the workplace.

Figure 3: Student exposure to laboratory techniques during internship, Makerere University 2011-2018.

3a - Heatmap showing each student's technical experiences



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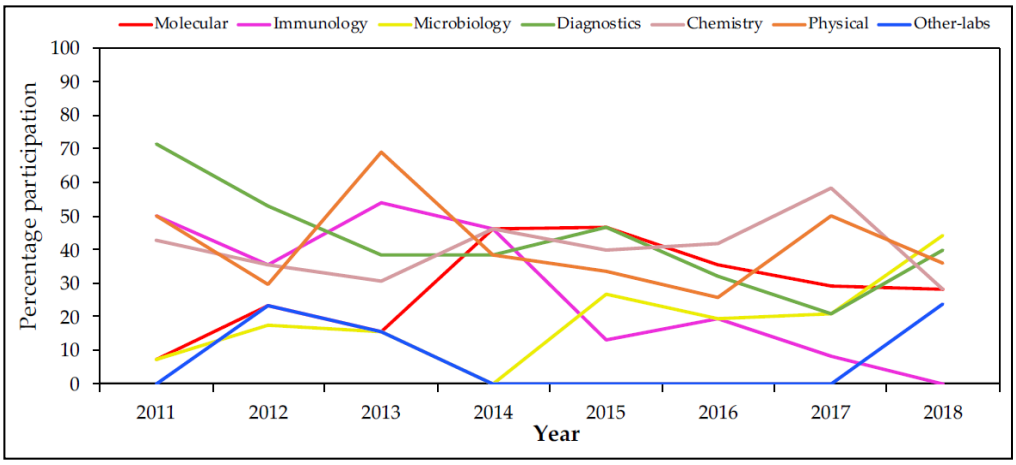
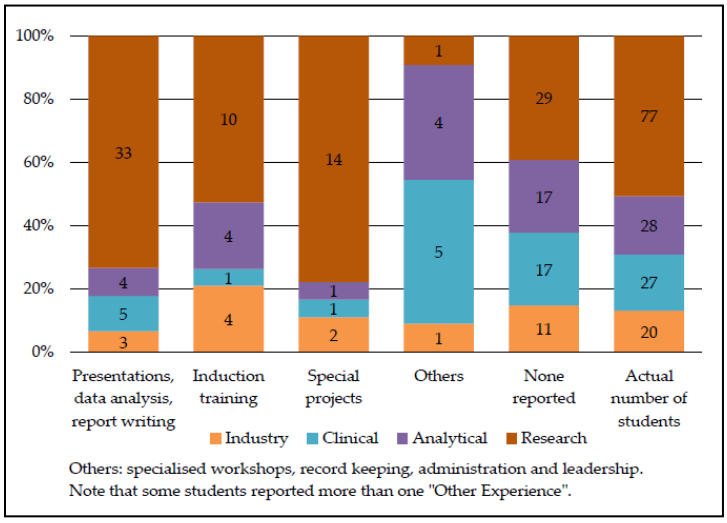
3b - Line graph of percentage participation in the various categories of laboratory techniques



Other Experiences

In addition to the core laboratory-based hands-on experiences, almost half of the students (73/152, 48%) reported that they had additional experiences during internship. The most frequently reported "Other Experiences" were data analysis and/or presentations and/or report writing (Figure 4). Notably, students who went to organisations in the Research category mentioned presentations, data analysis, and report writing, as well as special projects proportionally more frequently relative to students who went to the other categories (*Figure 4)* suggesting that organisations in the Research category are more likely to provide a broader internship experience. This can be attributed to the fact that in addition to laboratory-based activities, presentations, data analysis, report writing, and other activities such as journal clubs are routine at research organisations. According to the students who participated in the studies by McCune (2009) and Bullock *et al.* (2012) who use the terms "authentic learning experiences" and "authentic context" to describe the rich learning contexts of host organisations that provide realistic experiences of how scientists work, a characteristic of an "authentic context" is participating in presentation of work and in journal clubs.

Figure 4: Biochemistry (Major) students by internship organisation category and types of Other Experiences during internship, Makerere University 2011-2018.



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A few students (18/152) reported that they were given special projects during internship. All our Biochemistry (Major) students do a research project during their third year as a core curriculum requirement; however, the students who have a similar individual research project experience during internship may have an advantage over students who do not have the same experience with respect to additional skills gained. Support for this suggestion is provided by Hejmadi *et al.* (2012) who reported that compared to non-placement students, bioscience students who take the optional 1-year internship which includes a project need less research-skills support and require less help with their own write up when they are doing their on-campus final year research project. In addition, they perform better academically than their peers who do not take the internship after controlling for prior academic performance and other factors (Binder *et al.*, 2015; Gomez *et al.*, 2004; Hejmadi *et al.*, 2012). It would be of interest to document whether in our context, students who do projects during internship perform better on their third-year research project. In addition, it is conceivable that doing a special project in the work-place context influences the student's career decisions, and exceling in it enhances their chances of employment after graduation. It would therefore be informative to follow-up the students who do special projects during field attachment to determine the impact with respect to employment immediately after graduation and subsequent career path. At some organisations the special project is competitive and students who excel are awarded prizes (reported as "Benefits").

While we assume that all organisations take students through internship induction training, only 18/152 students reported this experience. It is possible that all the students were taken through induction training but the majority did not view it as an additional experience worth reporting about. Nevertheless, Smith (2012) observes that inadequate induction and preparation processes lead to an inferior student experience which in turn may impact learning outcomes negatively. At some of the organisations that receive many students, one of them is elected or selected to lead the others; such students reported this unique experience which we categorised as Administration and Leadership. Not every student can be selected to lead the group of internship students hosted at a particular organisation, thus it would be useful to follow-up the students who held these leadership positions during internship to determine the impact with respect to employment immediately after graduation. A few (6/152) students reported unique experiences such as attending a workshop on capacity strengthening for animal diseases surveillance and diagnostics, participating in record keeping and procurement as well as out-of-station field trips. A total of 52% (79/152) of the students did not report any other experiences; based on the reports it is not possible to tell whether this is because they did not have other experiences or whether they simply did not think the other experiences they had were worth reporting on.

Students' Perspective of Benefits and Challenges of Field Attachment

The following emerged as the most frequently reported benefits of internship: new skills and/or knowledge, networking, and experience of a professional environment (*Figure 5).* These benefits of internship have been documented in studies in different settings and disciplines such as by Chang *et al.* (2011), Cheong *et al.* (2014), Kaye *et al.* (2011), Maertz Jr, *et al.* (2014), Owusu-Acheampong *et al.* (2014), Renganathan *et al.* (2012) and are the reason why internship is acknowledged as a valuable component of university undergraduate programs.

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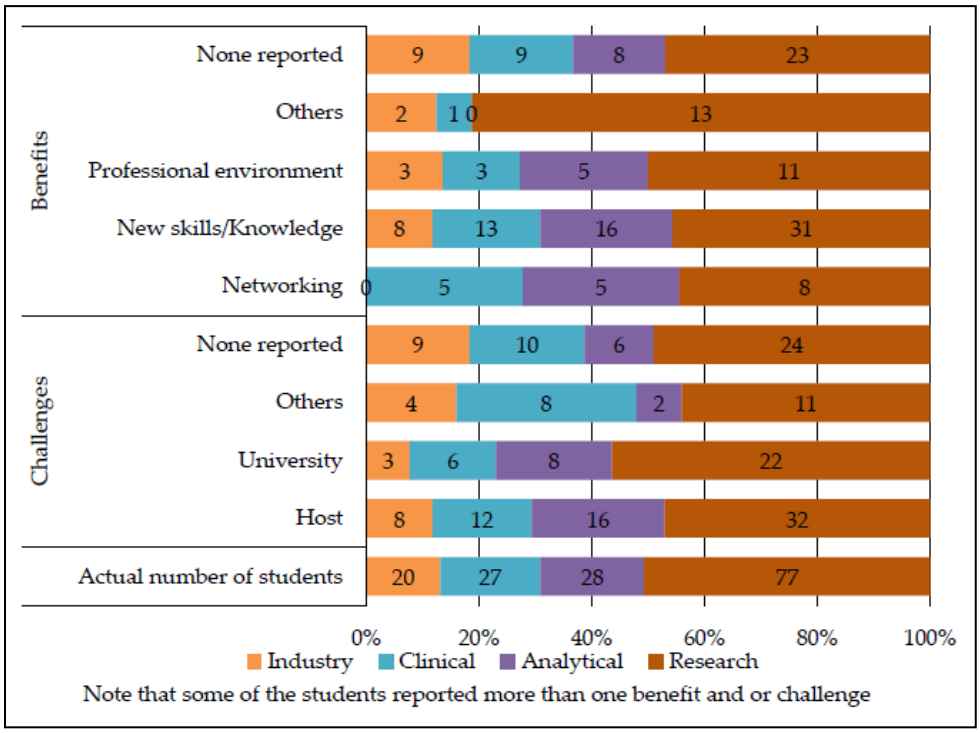
Figure 5: Distribution of perceived benefits and challenges of internship for Biochemistry (Major) students, Makerere University 2011-2018



Overall, 43% (65/152) of the students reported that they benefitted through new knowledge and skills, including inter-personal, computer, communication, and self-evaluation skills, in addition to the expected laboratory skills. The former is considered "employability skills", that is, skills that enable an individual use the more specific knowledge and technical skills that their particular workplace requires; they are core skills/generic skills/functional skills/skills for life that almost everyone needs for almost any job (Lowden *et al.*, 2011).. A study of 34 departments, including Biological Sciences, in eight universities in the United Kingdom found that work place experiences similar to Makerere's internship had a significant effect on the ability of graduates to find employment within six months of graduation or to secure employment in graduate-level jobs (Mason *et al.*, 2009). In contrast, teaching, learning, and assessment of employability skills by university departments did not have the same effect on graduates' ability to find employment signifying the central role work experience has on the development of employability skills (Mason *et al.*, 2009). In view of this, it will be useful to carry out tracer studies in order to establish if "employability" of our graduates was related to whether or not they reported that they benefited from internship through new skills. However, because not all students may have documented every benefit of their internship experience in their internship reports, it will also be important going forward to systematically evaluate the students' employability skills as a function of internship, and to explore, with the internship host organisations, how to deliberately include employability skills in the internship program.

About two-thirds of the students (103/152; 68%) reported that they faced one kind of challenge or another (*Figure 5*). The most commonly reported challenges were host-related, which the students perceived as directly affecting their hands-on experiences, such as inadequate laboratory space due to large numbers of interns, limited/restricted access to some laboratories, faulty equipment, and inadequate supplies. Concerns about safety, including absence of safety and protection gear, risk of exposure to hazardous chemicals and infectious diseases were also reported by nine students. Taken together, these particular challenges might reflect

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insufficient funding at the host organisations; this is plausible considering GERD as a percentage of GDP was a meagre 0.2% in Uganda in 2014 (UNESCO Institute for Statistics, 2019). Insufficient funding is compounded by increasing numbers of interns. Other challenges linked to the host organisations included power outages and or water shortage, poor organisation and time management, closure of organisation and charging a bench fee. Prior to the institutionalisation of internship at Makerere, internship was limited to a few programmes in the College of Health Sciences and others like Education whose internship host organisations were health facilities and secondary schools respectively. Over time, and with the institutionalisation of internship, new host organisations, especially private research laboratories and (small scale) industries have entered the internship host organisation space. As Biochemistry student numbers increase, the range of, and therefore the variability in the host organisations increases. With this increased variability there are likely to be more challenges. Because internship is relatively new to host organisations in Uganda especially in some spaces like industry, the organisations may not necessarily routinely include hosting internship students in their plans and activities, and therefore in their budgets. This suggests that long-term agreements (Memoranda of Understanding) may need to be established with these organisations so that they can plan and budget ahead and adequately for interns. Research on the effectiveness of internship indicates that universities and host organisations should have a strong and coherent relationship built on mutual benefit (Hora *et al.,* 2018; Maertz Jr *et al.,* 2014; Narayanan *et al.,* 2010). One of the ways WIL off-sets student costs is that students are fully integrated into on-going activities in the laboratories carrying out meaningful work that contributes to the outputs of the organisation as opposed to designing special activities for students which may not contribute to the outputs of the organisation. The advantage to the host organisation is that consumables and supplies are used productively, and the students provide free labour. Furthermore, if the host institution intends to take on new recruits, integrating students into the day-to-day activities provides the opportunity to observe their capacity to handle the work and the workplace, and to pre-develop them as potential new employees (Maertz Jr *et al.,* 2014). However, the students' capacity to contribute depends on the technical complexity of the work being done, and the students' "real work" needs to be framed carefully so that they do not feel they are being exploited (Maertz Jr *et al.,* 2014; Owusu-Acheampong *et al.,* 2014).

A total of 28 students reported challenges that could be attributed to the University such as limited time for internship, inadequate awareness of Biochemistry by the host organisation, limited briefing and supervision, and poor communication between the host and supervisor/ internship coordinators. The WIL evaluation framework proposed by Smith (2012) has supervisor access and induction and preparation processes as two of six evaluation domains. Inferior student experiences associated with inadequate supervisor access and inadequate induction and preparation processes are likely to impact learning outcomes negatively. Poor communication between the host and supervisor/ internship coordinators and poor supervision have also been reported as challenges in more advanced settings (Hejmadi *et al.,* 2012; Hora *et al.,* 2018). These challenges highlight areas for improvement, and since one of the goals of internship is to enhance and strengthen linkages between Makerere University and various stakeholders, it is critical that the Department of Biochemistry strengthens current efforts to create awareness about Biochemistry and how it contributes to various fields focusing on current and potential internship host organisations. One student decried long experiments and the exposure to dangerous chemicals, stating that it reduced her motivation to work. While this was an isolated case, it underscores the importance of (1) ensuring that students have positive internship experiences so that internship is not responsible for reduced motivation for a career in science; (2) carrying out tracer studies that can eventually inform curriculum improvements.

Strengths and Limitations of the Study

The major strength of this study is that all students' reports from 2011 to 2018 are included in the present study; it is not based on a sample of the reports and therefore it is a comprehensive examination of the Biochemistry (Major) internship program to 2018. Secondly, neither students nor academic staff knew this study would be carried out

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thus whatever was recorded in the reports was unbiased because it was not influenced by the idea that reports would form the basis of a study. However, because the study is based on students' reports, the findings depend on how thorough the students were in writing their reports and how closely they followed the generic University-wide guidelines they were given. Some students did not report other experiences, benefits or challenges and it was not possible to decipher whether they actually did not have anything to report or whether it was an omission. Therefore, where no other experiences, benefits or challenges were reported we noted, "None reported" as opposed to "Nothing to report".

CONCLUSIONS AND RECOMMENDATIONS

This retrospective analysis of the Biochemistry (Major) internship program at Makerere University in Uganda based on students' written reports found that despite limited research and laboratory infrastructure and a low level of industrialisation, students got relevant technical hands-on experience and exposure during internship. Additionally, some of the students had non-laboratory-based experiences such as data analysis, and benefits such as gaining 'employability skills' that enhance their work-place readiness. The students faced challenges that reflect the limited research and laboratory infrastructure which might broadly be linked to the well-documented as yet limited investment in the science and technology sector, compounded by increasing numbers of interns.

A key recommendation from this study is that for successful internships in low-resource settings, Universities need to strengthen engagement with host organisations in order to enhance the students' internship experiences. This engagement may range from involving them in setting broad objectives and planning the internship program, to establishing formal MoUs within the Universities' legal frameworks. Secondly, in view of the increasing number of students, innovative opportunities for internship from the biochemistry perspective, such as the oil industry, wildlife research, the fisheries industry and cosmetology should be explored. Alongside this, out-reach activities by biochemists need to be intensified so that potential host institutions appreciate how Biochemistry can contribute to their organisations. Similar efforts have to be made internally so that students have a good understanding of how Biochemistry contributes to various fields before they go for internship. Evaluation (as opposed to student assessment) of internship should be integrated into the design of the internship, and should involve faculty and internship supervisors. Evaluation is important for demonstrating how internship contributes to the students' training, which in turn will garner further support for internship. Evaluation is also critical for describing the challenges involved such that improvements can be made. Further research is needed to describe in detail what an "authentic context" is in low-resource settings and from the point of view of faculty and students. This knowledge can then be used to develop criteria for assessing host organisations.

While field-based practical training plays a key role in human capital development, there are challenges for Biochemistry internship programs in low-income countries like Uganda where research and laboratory infrastructure is inadequate and the level of industrialisation is low. In describing the Biochemistry (Major) internship program at Makerere University, including the benefits and challenges, we have provided a point of reference for similar bioscience programs in other low to middle income countries. We have shown the kinds of entities, both public and private, that can host students and provide an acceptable internship experience. It is envisaged that these findings will stimulate a conversation about internships in Biochemistry and in the Biosciences in general, with the goal of sharing best practices as well as enhancing overall training in Biochemistry and in the Biosciences in general within low-income countries.

Declarations

Availability of data and materials: The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: None

Authors' contributions: KR, JM and RKB conceived the idea and developed the data

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extraction tool. KR, JM and FMS pre-tested the data extraction tool. FMS, KR and RKB extracted the data. KR, JM, FMS and RKB coded and analysed the data. All authors (KR, JM, KHA, FMS, JI, RG, JK, PCV and RKB) discussed the results and contributed to the manuscript. All authors approved the final manuscript.

Ethical considerations:

This is a retrospective study based on students' academic reports and is for purposes of program evaluation. Data from reports was anonymised.

Abbreviations

ELISA	Enzyme-linked immunosorbent assay
FACS	Fluorescence-activated cell sorting
GCLP	Good clinical laboratory practice
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Experimental Development
HEIs	Higher Education Institutions
MoU	Memorandum of Understanding
PCR	Polymerase chain reaction
SSA	sub-Saharan Africa

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