POINT LOMA NAZARENE UNIVERSITY

# A comparative study between two approaches to university STEM education in the Democratic Republic of Congo: The effects of inquiry-learning on student learning outcomes and plagiarism rates

A thesis submitted in partial satisfaction of the
requirements for the degree of
**Master of Science**
in General Biology

by

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I dedicate this thesis to my loving parents who instilled in me the value of curiosity and adventure; to my sister who paved the way; to my family members and friends who hosted me across several countries and opened my eyes to this wide world. A special thank you to Lauren and Dr. Ben Lawson, whose love and generosity were the foundation of this project.

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I would like to acknowledge the students, staff, faculty, and volunteers that make Université Chrétienne Bilingue du Congo the special place that it is. The university's slogan: "being transformed to transform" is evident in the lives and work of those invested in UCBC.

## Abstract of the Thesis

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Research on higher education in the Democratic Republic of Congo (DRC) is virtually absent (Zavale & Schneijderberg, 2020). Science, Technology, Engineering and Math (STEM) programs are being encouraged by the global community without assessments of the learning outcomes of the students enrolled (Blom, Lan & Adil, 2015). This research project compared two STEM programs within the same university in the North Kivu province of the DRC. One program institutes non-semesterized, intensive courses with little resource availability and no homework assignments. In contrast, the reformed version of the same program follows a semesterized course calendar and uses inquiry-based learning pedagogy in line with current models of internationalized education. This study identified and studied differences in teaching, classroom atmosphere, and science literacy learning outcomes between the two groups using a mixed methods approach. It was found that teaching styles were similar as measured by the

Reformed Teaching Observation Protocol even though the pre-reformed program lacked a reformed curriculum. However, students in the reformed program had higher levels of science literacy than their peers in the pre-reformed program despite both groups having educational backgrounds interrupted by both political unrest and health pandemics. Furthermore, it was discovered that plagiarism in the pre-reform program was prolific and unchallenged by the institutional leaders. In conclusion, the reformed program represents a promising model for achieving STEM education in a resource-constrained environment that leads to improved student learning outcomes and lower plagiarism rates. This research presents data that is currently absent within the field of higher education in the DRC.

**Keywords:** the Democratic Republic of the Congo, higher education, STEM, student learning outcomes, reformed teaching, inquiry-based learning

# Introduction

The Democratic Republic of Congo (DRC) is 12th on the list of least developed countries in the world (Human Development Report, 2020). Despite this fact, the nation has incredible wealth and provides more of the world's cobalt (essential for many electronics) than any other nation (Scheele, De Haan & Kiezebrink, 2016). The juxtaposition of natural resource wealth with human poverty can be traced back to the horrific colonial rule of Belgium; King Leopold is held responsible for the death of 10 million Congolese people from 1885 to 1908, by some estimates, while claiming ivory and rubber for personal gain (Moore, 2001). Today ivory and rubber have been replaced by mineral extraction, but the equitable distribution of wealth remains a dire issue. The labour force extracting these minerals and gaining high salaries is largely foreign, with only the lowest paying and most dangerous jobs going to local people (Rubbers, 2020). Science, Technology, Engineering and Math (STEM) educated individuals may gain access to this booming industry, but education in the DRC is broken, both at an institutional level and the governmental level (De Herdt & Titeca, 2016). With a ministry of education that is nearly bankrupt, offering high-quality education is difficult for primary and secondary schools in the DRC with teacher training programs being supported by international development institutions (Lund, 2020). The state of higher education in the DRC is virtually unknown and unresearched, aside from a few broad, cross-regional studies (Zavale & Schneijderberg, 2022).

Although STEM education remains an important means of getting locals into the lucrative economies of the region, STEM programs are also the costliest discipline for a university to offer, averaging almost four times as much per student than a humanities major (Hemelt, Stange, Furquim, Simon & Sawyer, 2018). Furthermore, without knowledge of the quality of such programs in the DRC, it is impossible to know whether graduates are qualified enough to fill high-paying positions in their local economies.

This study took place at a higher education institution (HEI) in the north-eastern region of the DRC which currently is in the midst of reforming an established STEM program. This allowed for a comparison between a normative, pre-reformed STEM program and a reformed, inquiry-based program striving for a more internationalized level of education. This study compared both the teaching style by faculty and the achievement of learning outcomes by students in the new program with those in the original program. It aimed to determine if the curriculum's inquiry-based learning approach is successful by using a mixed methods research approach. Specifically, data was collected and analyzed in two areas: 1) assessing the main differences in teaching and learning strategies in the reformed and original classroom and 2) assessing students' science literacy and numeracy level as an indicator of learning outcomes.

## Literature Review

### Theoretical perspective

The theory of learning known as constructivism operates on the belief that knowledge is built by the learner rather than imparted upon the learner by the instructor. It is thought that this occurs through processes facilitated by both an individual's individual mental practise and through interactions and relationships with peers and instructors. This theory of learning was primarily developed by Jean Piaget and Lev Vygotsky over the course of their lives (Jean Piaget: 1896-1980, Lev Vygotsky 1896-1934). Inquiry-based learning was first described by John Dewey (1910) who defined the process as having a teacher present a problem and then partner with the student to solve it. Dewey's theory has expanded into a basic understanding among practitioners of reformed teaching that students are participants in their learning and that knowledge construction necessarily occurs collaboratively (Daniels, 2002).

This current research project, therefore, has the intention of answering its proposed questions under the constructivist framework by considering both the relationships the students have with each other, their society, and their instructors, as well as the individual's interactions with the intervention methods of the reformed-program curriculum. Each of these relationships is considered equally important to understanding student learning outcomes. Learning institutions teach accordingly by offering students both group work and personal reflection (Kalina & Powell, 2009). The framework and assumption of this research project are that an inquiry-based learning approach (i.e. constructivist approaches and Dewey's model of instructor/student partnered learning) can be a successful method for students to build new knowledge in STEM (Lord, 1999).

## The history of education in the DRC

Congolese independence from Belgium was declared in 1960. Prior to this, education in the DRC was segregated, with a Belgian schooling system reserved for European students, and a Congolese education system led by Catholic and Protestant missionaries (Depaepe & Hulstaert, 2015). The HEIs created for the Congolese population had the sole purpose of proselytizing students into the faith and teaching practical skills in areas such as agriculture and preaching (ibid.). After independence was established, education modernization began to take place, with the new nation's original constitution of 1964 stating that education was to be compulsory and free. Unfortunately, this article was omitted in 1974, but then restored in the third version, leading to an interruption in education for many individuals from a mere generation ago (DRC Const. Art. 33, 1967, DRC Const.1974) (De Herdt & Titeca, 2016). Nevertheless, today there are still many challenges standing in the way of free and compulsory education: French continues to be the official language, as set by the Belgian colonial rule, rather than one of the DRC's four national languages (Boyle, 1995; DRC Constitution, 2005). In selecting a colonial language for primary, secondary, and HEIs, access to education remains an issue, especially in rural areas where French is not widely spoken (Woods, 1994).

HEIs were significantly less prominent in central African countries during the era of colonial reign as compared to the North and South regions of the continent (Woldegiorgis & Doevenspeck, 2013). The first university to open in the DRC was the Catholic missionary-funded and led L'universite Lovanium in 1954, shortly before independence was declared (Boyle, 1995). Importantly, this institution was not funded by the Belgian government, as it was a potential risk to the stability of the Belgian rule, which feared that in creating a "Congolese elite", uprisings against European power holders would occur (Depaepe & Hulstaert, 2015). As education was systemically hindered, finding teachers with sufficient training and certification was difficult and remains difficult in many areas spanning the DRC, resulting in a paucity of PhD-holding instructors (Majaliwa, 2020). Nevertheless, as globalization continues to affect all the world's nations, so has the push for HEIs to find innovative ways to internationalize their practices (Wan & Geo-JaJa, 2013).

**Internationalization of Education in the DRC**

Internationalized education can be described as a cross-border matching of curriculum and pedagogy, with a focus on the standardization of education that allows members, such as faculty and students, the ability to move within the global network and be able to cope with the academic processes regardless of geography (as an instructor or student) (Wan & Geo-JaJa, 2013). HEIs in many parts of Africa are less learner-centred and more teacher-centred, a reflection of the sociocultural norms within African society (Muganga & Ssenkusu, 2019). Learner-centred pedagogy is a central trait of internationalized education, which is based on social constructivist theories (Lord, 1999) and is a more common trait of the Global North's sociocultural framework (Tabulawa, 1997, 2013). There have been critiques of higher education internationalization in countries like the DRC, as internationalization can lead to the depletion of local knowledge and push societies to become homogenized (Tabulawa, 2003, 2009). In contrast, if HEIs are too narrowly focused on local issues, they can be alienated from a quickly globalizing world and graduates can be excluded from economic opportunities. Finding a balance between these two positions requires assessments of student learning outcomes. The university at the centre of this research study aims to offer both a localized curriculum focusing on DRC-specific issues as well as to produce a standardized STEM program with graduates qualified to enter a globalized workforce.

The DRC is a politically fragile state and has a long history of violence and instability; the government does not consistently support the education sector through instructor training or resource supply (Lund, 2020). Primary and secondary students in the DRC are faced with numerous social, economic and political barriers that have led to punctuated and insufficient education (Brandt, 2014). This can leave students underprepared for higher education, which forces HEIs to compromise quality to counter knowledge gaps in their incoming students or provide bridging programs to help them catch up further handicapping the ability to internationalize their curriculum.

**Bridging programs**

Bridging programs go by many names including "pathway", "foundation", "direct entry", and "sub-degree" programs, but their purposes are usually similar: to help students close their knowledge gaps through the delivery of more general concepts, extracurricular activities for confidence boosting, and support for learning healthier academic habits (Agosti & Bernat, 2018). Bridging programs have been used in lower and middle-income countries as a method to help "bridge the gap" and there is empirical evidence to suggest their effectiveness in countries such as South Africa and Uganda (Grayson, 1997; Ssempebwa, Eduan, & Mulumba, 2012).

**Comparable bridging programs**. A study at the University of Natal observed that black students in a STEM-focused degree program performed significantly worse than white South African students (Grayson, 1996). The University of Natal then proposed implementing a bridging program to help close this gap and has been developing this bridging program for nearly two decades. Their bridging program focuses on the remediation of six traits that were found to be underdeveloped in the black South African student population: background knowledge, attitude, behaviour, cognitive skills, practical skills, and metacognition (Grayson, 1996, 1997). Grayson (1997) does not provide data to show whether students caught up in performance outcomes but concludes by mentioning that although it is impossible to overcome a lifetime of educational barriers in one year, the students are benefitting significantly from the program. The research conducted on this "significant" change was assessed using interviews and not quantitative data. Aside from not being able to measure learning outcomes, this program also does not offer any insight into the professional outcomes of these students upon graduation. Another difference from this South African program to one in a least-developed country like the DRC, is that South African schools contain a population of students with strong educational backgrounds from internationalized institutions. Under the theory of social constructivism and Vygotsky's (1930-1934/1978) findings that learning occurs through being engaged with peers who have slightly higher levels of skill, South African bridging students will have more opportunities for such interactions. In other words, underprepared students are surrounded by better-prepared students and this is not comparable to the situations in the DRC, even though South Africa has a comparable colonial history. For example, it is not listed as a fragile state by the Organisation for Economic Co-operation and Development (OECD, 2020), so the same program may not be effective in the DRC. Furthermore, the Global Coalition to Protect Education from Attack (GCPEA) denotes the DRC as being a highly affected country while South Africa is listed as low (GCPEA, 2020). There is evidence to suggest bridging programs are effective, but there are no studies comprehensively showing their successful implementation or efficacy in HEIs in fragile states and least developed countries such as the DRC (Zavale and Schneijderber, 2022).

### Inquiry-based learning at UCBC

Inquiry-based learning has empirically been shown to improve the learning outcomes of students in science programs in comparison to traditional teaching methods (Abdi, 2014; Laksana, 2017; Panasan & Nuangchalerm, 2010). However, there is some conflicting evidence showing that inquiry programs at the postsecondary level do not increase learning outcomes in comparison to traditional teaching methods, and can lead to confusion and frustration in students (Gormally, Brickman, Hallar & Armstrong, 2009). Understanding whether inquiry-based learning is effective requires a close look at the institution, its ability to deliver an inquiry-based curriculum, and the willingness of other gatekeepers to adopt it correctly.

### Research challenges in least developed countries

Choosing a research design to assess such things as institutional shifts in teaching styles and program delivery is difficult in places like the DRC, which falls under the official category of a least developed country, according to the UN (UNCTAD, 2021), as there are very few examples to follow in the existing body of research. Furthermore, HEIs in least developed countries are even more difficult to research than in lower and middle-income countries, as there is an extreme lack of infrastructure. The DRC, for example, has merely 1,200 km of paved roads covering 2,300,000 km^2 of land area (Mbaucaud, 2005). Compare this to the UK, which is nine times smaller, and has 20 million fewer people, but 422,000 km of paved roads. Mobility for a researcher often requires either prohibitive amounts of time travelling dangerous roads or prohibitively expensive chartered flights.

Following the infrastructural barriers are inherent instability within institutions and the bodies that govern them (Titeca & De Herdt, 2011). Institutions lack autonomy, and with a dysfunctional and financially weak education system that struggles with corruption at the helm, institutional policies change often, making any kind of consistency and evenness impossible (Herdt & Titeca, 2016). This means conclusive statements or longitudinal studies are difficult with such continual disruptions and fluidity of processes. Nevertheless, the success of bridging programs and reformed, internationalized education in HEIs in low-income countries like the DRC will not be known until research is carried out, and finding the most appropriate tools is important.

**Assessing the level of reform in the classroom**

The Reformed Teaching Observation Protocol (RTOP) is a classroom observation tool designed to assess how close an instructor is to meeting reformed teaching standards (Piburn et al, 2000). Implementing a reformed curriculum and bridging programs successfully requires that instructors have the knowledge and training necessary to carry out reformed teaching methods. The RTOP tool allows for the measurement of teaching methods and has a high degree of reliability among trained tool users (ibid). Observational tools like this allow for a baseline to be determined to measure the quality of reformed programs and should be used before their effectiveness is studied. The RTOP tool has 25 items and is broken down into three main categories: teaching content, teaching style, and classroom culture. Teaching that lacks reformed techniques may look like lecturing without engaging students, teaching without hands-on learning opportunities, and incorporating limited, if any, group activities for conversation among peers, as is common in many low-income countries (Tabulawa, 1997).

Reformed teaching and inquiry-based learning are internationalized pedagogical methodologies and are common in the training of pre-university teachers (Aditomo, Goodyear, Biluc & Ellis, 2011). For teachers in a primary and high-school setting, quality teaching is measured by the preparation and qualifications received through preservice education programs and teaching practises ie. the actual classroom behaviours of the teacher (Forgione, 1999). Preservice training is not required for university-level instructors, but internationalized education has inquiry-based learning embedded in the curriculum, requiring instructors to move away from lecture-centred teaching styles (Aditomo, Goodyear, Biluc & Ellis, 2011). Furthermore, HEIs often have policies and processes in place to ensure that instructors teach to an institutionally-set standard, based on empirically driven methodologies (Justice, Rice, Roy, Hudspith & Jenkins, 2009). Likely, this is not the case for low-income and least developed countries like the DRC, although it is not possible to make a statement given the complete lack of data. There is a great need for data on what classroom instruction looks like at the post-secondary level in the DRC.

## Science literacy

One way to measure the effectiveness of this HEI, and specifically its STEM program, is to look at how students' "scientific thinking" or "science inquiry" skills develop, through the medium of their assignments. Research shows that the development of scientific knowledge (a collection of isolated facts) is separate from the skill of scientific thinking, which is defined as a combination of theoretical knowledge, curiosity, an understanding that theories must be falsifiable, respect and understanding of evidence, and an understanding that evidence is distinct from the theory (Kuhn, 2011).

The HEI being studied for this project has an academic catalogue for its pre-reformed STEM program which outlines the learning outcomes and states that students will gain transferable skills (written as "poly-competencies") allowing them to work in a wide range of professions upon graduation (UCBC Catalogue LMD, 2016) (see Appendix A). However, the document only provides learning outcomes specific to course disciplines and does not clearly list which transferable skills are targeted. These vague, domain-general skills that are listed should lead to science literacy, although assessments of this are lacking and a clear definition of the meaning is absent. Measuring whether this is occurring has to start with a clear definition of science literacy.

Gormally, Brickman and Lutz (2012) used large international and governmental education research bodies (AAAS, National Academy of Science, OECD) to construct a comprehensive list of science literacy skills, shown in Table 1. These skills are the foundation for a widely used science literacy assessment tool called the Test of Scientific Literacy Skills, filling important research needs that focus on being able to measure the learning outcomes of students in STEM programs and track their progress (ibid.). Science reasoning is an iteration of science literacy, and there exists a large body of research offering well-tested tools and assessment methods for STEM students.

Table 1.

A List of *Scientific Literacy Skills. The 9 science literacy skills and examples of each are divided into two groups: skills to do with understanding the scientific method and skills to do with data analysis and organisation. (*Gormally, Brickman & Lutz, 2012)

| | Examples of common student challenges and misconceptions |
|---|---|
| I. Understand methods of inquiry that lead to scientific knowledge | |
| 1. Identify a valid scientific argument | Inability to link claims correctly with evidence and lack of scrutiny about evidence<br>"Facts" or even unrelated evidence considered to be support for scientific arguments |
| 2. Evaluate the validity of sources | Inability to identify accuracy and credibility issues |
| 3. Evaluate the use and misuse of scientific information | Prevailing political beliefs can dictate how scientific findings are used.<br>All sides of a controversy should be given equal weight regardless of their validity. |
| 4. Understand elements of research design and how they impact scientific findings/conclusions | Misunderstanding randomization contextualized in a particular study design.<br>General lack of understanding of elements of good research design. |

| | Examples of common student challenges and misconceptions |
|---|---|
| II. Organize, analyze, and interpret quantitative data and scientific information | |
| 5. Create graphical representations of data | Scatter plots show differences between groups.<br>Scatter plots are best for representing means, because the graph shows the entire range of data. |
| 6. Read and interpret graphical representations of data | Difficulty in interpreting graphs Inability to match patterns of growth, (e.g., linear or exponential) with graph shape |
| 7. Solve problems using quantitative skills, including probability and statistics | Guessing the correct answer without being able to explain basic math calculations<br>Statements indicative of low self-efficacy: "I'm not good at math." |
| 8. Understand and interpret basic statistics | Lack of familiarity with function of statistics and with scientific uncertainty.<br>Statistics prove data is correct or true. |
| 9. Justify inferences, predictions, and conclusions based on quantitative data | Tendency to misinterpret or ignore graphical data when developing a hypothesis or evaluating an argument |

**Science reasoning**

Science reasoning can be described as the ability to overcome embedded alternative conceptions about the natural world incompatible with current scientific theories (Lawson & Thompson, 1988). This journey a student makes from reasoning with alternate conceptions to reasoning with non-intuitive scientific theories after formalized education can be captured through various tools, including the Lawson Classroom Test of Scientific Reasoning (LCSTR) (Lawson & Thomson, 1998). Lawson and Thomson (1988, 2000) categorized these two mind frames into concrete operational reasoning, for the stage in which alternate conceptual beliefs drive reasoning, and formal operational reasoning, for when a student can use complex, non-intuitive scientific concepts to reason. The validity of this tool has been long established and it continues to be used to gather evidence of learning outcomes achieved by students from middle school to early college in STEM programs (Bao et al. 2009; Hrouzkova & Richterek, 2021; Zhou et al. 2021).

An example of a typical distribution of first-year university STEM students' scores on the LCTSR can be viewed in Figure 1 (Hrouzkova & Richterek, 2021). In this study, 446 first-year science majors took the LCTSR, prior to beginning their first year of study. The score achieved on the test relates to the stage of scientific reasoning that an individual falls into. They found that most students entering their first year of a science degree exhibited transitional reasoning (having some ability to engage with formal operational reasoning), with approximately a quarter falling into both the concrete operational and formal operational categories.

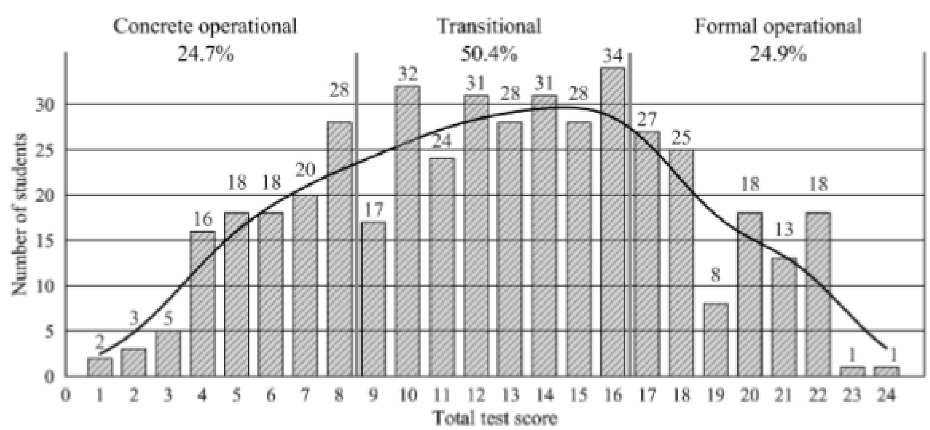



Figure 1. *Lawson's Classroom Test of Scientific Reasoning Distribution and Reasoning Categories. Of 446 first-year chemistry and physics students in the Czech Republic (published results) for comparison.* **Note:** Reprinted from Hrouzkova, T. and Richterek, T. (2021)

Having a list of skills defining science literacy as outlined in Table 1 and tests like the LCTSR allow for educators to map student outcomes and institutional patterns of success or failure, but in order for these tools to be effective, student work needs to be original and mirror their thinking. This leads to the perennial problem of plagiarism.

**Plagiarism in higher education as a barrier to assessment**

Plagiarism is a universal problem, and there are many studies providing data on its prevalence in HEIs, even in well-resourced settings (Pupovac & Fanelli, 2015). Plagiarism takes many forms and there are various definitions in the literature addressing this issue. For these reasons, it is hard to quantify just how problematic plagiarism is in any given institution. A few examples that highlight the spectrum of academic dishonesty are the extreme instances of “paper-mills" being used, in which students purchase entire essays. Additionally, “patchworking” occurs when students take chunks of another’s work and then change around words and structure and finally, citing work improperly which can be either intentional or innocent. Each of these types of plagiarism can cloud the ability of instructors to properly assess student learning outcomes.

There is evidence that suggests a combination of these forms of plagiarism are more rampant in low-income countries (Ana, Koehlmoos, Smith & Yan, 2013), but a paucity of research does not allow for conclusive statements to be made on patterns, causes, or implications. McCabe (2005) points out a potential reason for this observed increase in plagiarism gleaned from his research in the US: institutions that do not have systems in place to quell plagiarism and, in any way allow it, find honest students frustrated that those who are dishonest may have an unfair advantage leading to an apparent increase in overall academic dishonesty. In other words, institutional complacency encourages academic dishonesty. McCabe (2005) points out that a lax institutional culture is more common in programs with large enrollment numbers and lower resources to check for plagiarism.

Although it is difficult to gain access to locations like the DRC to determine student plagiarism rates, it is known that many of these institutions often have high enrollment and low resources (De Herdt & Titeca, 2016). Institutions in LMICs and least developed nations, like the DRC, often lack the capacity and resources to implement robust investigations, punishments, and prevention measures which are also known factors that suppress plagiarism rates (Ana, Koehlmoos, Smith & Yan, 2013).

Another lens to view the problem of plagiarism comes through the social constructivist theory of learning: social behaviours surrounding plagiarism are complex and constructed throughout a person's life (Curtis & Tremayne, 2021; Ercegovac & Richardson, 2004; Park, 2003). Equally robust pedagogy, resources and teacher training must be institutionally present throughout all the stages of learning so that students have a chance to construct meaningful knowledge about academic honesty (Ercegovac & Richardson, 2004). If plagiarism is as common as research suggests in lower-income countries, it must be assessed in student work before looking at levels of science literacy.

## Research Questions

With the sparse literature available on higher education in the DRC and, particularly the paucity of data that exists on STEM education, the following questions are posed:

What are the differences between the pre-reformed and reformed groups in the STEM program at this higher education institution (see Table 2 for a breakdown of student groups)? More specifically:

1) What are the differences in program structures and teaching styles?

2) What are the differences in the achievement of the student learning outcomes?

   a) Is there a significant amount of plagiarism present? If so, does it differ between programs?

   b) Is there a difference in students' baseline mathematical abilities and is there a change in mathematical ability over time for students in the reformed program?

   c) Is there a difference in students' science literacy skills?

# Methods

**Research design**

This study used a mixed method approach with both qualitative and quantitative data collection techniques. This has allowed for a more nuanced look at the processes of the HEI at the centre of this study and its overall educational values, strengths and shortcomings while respecting its place in a fragile state. Because there is a lack of information on higher education in the DRC in general, the qualitative aspects of this project were of greater importance. Generating an overall understanding of the state of this institution, and how it functions and copes with resource scarcity, required a broader research design. The qualitative research was, therefore, more heavily relied on to capture complexities involved with a STEM program in a least-developed country, while the quantitative data provided a narrower look at student achievement.

All data collection occurred in partnership with the applied science program staff and faculty at the HEI in the DRC. This study was conducted in compliance with the Point Loma Nazarene University Institutional Review Board policies and procedures and informed consent was collected from each student involved. Participation in activities for this project took place during class time.

**Study site, programs of study, and participants**

Université Chrétienne Bilingue du Congo (UCBC) is a small, private university located in the town of Beni in northeast DRC. It has a student body of approximately three hundred students living within the UCBC campus region. It was established in 2006 by a team of educators including Dr. David Kasali, who spent a career as a postsecondary educator and time as the president of Africa International University in Nairobi, Kenya. Feeling the need for a high-quality HEI in his hometown of Beni, Dr. Kasali recruited a team of qualified administrators and professors to found UCBC. Tuition is approximately $2,200USD/year; students are required to pay $400 of this with the rest being matched by the university through outside, international donors. The coordination of this comes from UCBC's non-profit governing body: Congo Initiative (CI). CI is a registered not-for-profit headquartered in Indiana, USA and hosts several other organizations within Beni.

UCBC has five academic departments: Applied Science, Communications, Economics, Theology, and Law. There are also specializations or "distinctive" including environmental sustainability and a campus work program that partners with agribusiness and GIS mapping that students can select courses in, much like a minor. Graduates of UCBC are 39% female which is in line with the national trend in higher education in sub-Saharan Africa which has yet to achieve equity in the representation of females (Majaliwa, 2020).

After recruiting a qualified Ph.D. holder trained in physics at the University of Michigan, the university planned to reform its current Applied Science program to a higher quality, internationalized program (see Appendix B for an outline of learning outcomes) . The reformed applied science program requires that students sit for an entrance math exam - a new assessment not required by the pre-reformed applied science program and representing one of its most impactful changes. Requirements like entrance exams can be difficult for HEIs to make as the government must grant approval of entrance requirements (Majaliwa, 2020). The UCBC entrance exams are important to student success in rigorous programs as grades are not listed by subject on secondary school transcripts. Instead, grades are given as a blended average of all courses taken under the umbrella of broader categories like “math,” making it hard to assess a student’s strengths and weaknesses per subject (Talwanga, 2015). Despite a mixed ability in literacy and computer skills, students are expected to have a minimum level of numeracy to enter this new reformed program.

Although the reformed program was granted permission to institute an admissions test for mathematical abilities, a literacy test for English and French was not included. Since the literacy levels of students at UCBC in both the reformed and pre-reformed program, as well as all students in the DRC, are not assessed, it is likely that many students struggle with fundamental levels of literacy due to a lack of resources and trained teachers in primary and secondary schools. An added level of difficulty for students at UCBC with respect to the development of their fundamental literacy is that UCBC is a bilingual institution; students are expected to be fluent on an academic level in both French and English by the end of their degree. Ongoing debates continue among the faculty about whether this is causing more harm than good, especially as many of the English-speaking instructors have fled Beni due to the recent periods of unrest, as well as the ebola and Covid-19 crisis. What remains are non-native English-speaking faculty, stretched thinly across the disciplines. As evidence suggests that general literacy is a key factor in science literacy, this should be considered when reviewing the data

(Schaffer, Ferguson and Denaro, 2019). Namely, some of the student artifacts that were analysed for this study were completed in English and some in French, but the literacy level of the students in either of these languages is unknown.

Table 2 outlines the four student cohorts in this study and their descriptions. Currently, the degree is four years in length for both the reformed and pre-reformed applied science programs. However, this has fluctuated and in the recent past, the program has been only three years in length. L0 represents the bridging year making the reformed program unofficially four years in length and is set as a buffer against governmental requirements to shorten the program to three years.

Table 2

*A Description of the Student Groups Within the Study. Recently, the government regulations changed requiring that degrees be no longer than 3 years. The applied science program was a four-year program in 2018, so it has been shortened for the current senior students from when they began their degrees.*

| **Descriptions of Student Groups in UCBC's Two Applied Science Programs** | |
|---|---|
| **Level 0 (L0)**<br>**n = 17** | ● This is the student group that represents the unofficial bridging year.<br>● Students in this group must pass an entrance exam with questions pulled from a diagnostic skills test question bank used by teachers for high school aged students.<br>● Most students are high school-aged, but some students may be older after having taken a break from school, or after transferring from a new program. |
| **Level 1 (L1)**<br>**n = 19** | ● This group of students represents those in the official first year of the three-year, reformed Applied Science program<br>● Students in this group split into either computer programming or mechanical engineering |
| **Level 2 (L2)**<br>**n = ~ 40** | ● This group of students represents those in the third year of the pre-reformed program.<br>● They will be the last group of students to complete the program which is being phased out by the new reformed program<br>● They will take 1 week to 2 week-long intensive courses throughout the academic year.<br>● At the end of the semester, they will sit for all course exams in the same period. |
| **Level 3 (L3)**<br>**n = ~ 40** | ● This is the group of students in the final year of the original program.<br>● They follow the same academic structure as L2 students with the added requirement of completing a senior year thesis. This is a completely independent project in which they work with a faculty advisor. The final document is approximately 70 pages in length and must go through a defence process. (This will continue to be a requirement for the L0 and L1 students once they reach their final year.) |

**Reformed program structure.** The structure of the reformed program follows a semesteralized approach with courses lasting 7.5 weeks in length and following a set schedule, with courses designed and planned prior to the start of the academic year (see Figure 2 for the schedule for reformed students during this study). Each course has corresponding textbooks and/or reading requirements available online or in the school library. Students are given daily homework assignments which are marked and recorded so that their progress is tracked (for a list of the learning objectives for the first year of the program. The reformed program is in its second year and will eventually replace the pre-reformed program. As of February 2022, the reformed program has been operating for 2 academic years. The class size for L0 and L1 is 19 students, although the original cohort has decreased in size due to the financial constraints of some students and a few students not being able to pass the requirements.

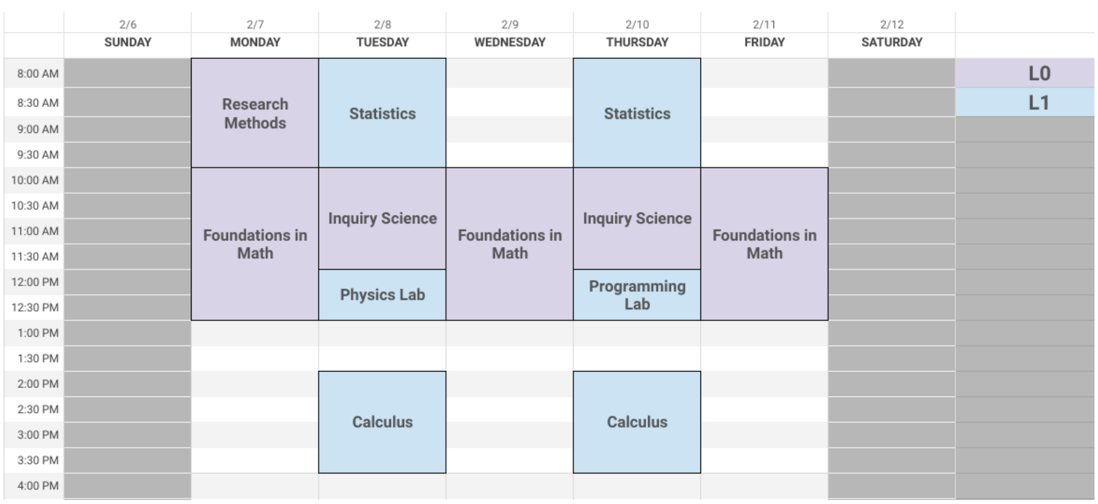



Figure 2. *Reformed Program TimeTable. Time table for L0 and L1 students in the first quarter of their semester (the time period of this project).*

**Pre-reformed program structure.** The pre-reformed program does not follow a semesteralised course delivery format like the reformed program but relies instead on visiting professors to teach intensive courses over the span of one to two weeks. These “intensives” typically take place from Monday to Saturday from 9:00 am and 4:00 pm, they are lecture-based, and some courses have lab activities. There are no homework assignments or textbooks, nor any direct feedback from the professors. To highlight the difference, the reformed students have the same three instructors for their entire academic year (for applied science courses). Pre-reformed students lack the opportunity to build a relationship with the travelling instructors as they quickly lose touch with them once the intensive courses conclude. The L2 and L3 class sizes (making up the pre-reformed group of students) have over 40 students in each making the ratio of students to instructors twice as large as the reformed student classes.

The structure of the program has problematic aspects as well: pre-reformed students are required to write their final exams for all courses taken throughout the semester during one exam week held at the end of the semester (UCBC has two semesters per academic year). This can sometimes be many months after they completed a particular course.

A final note on the major differences between the reformed and pre-reformed programs lies with resource access (see Table 3). Although the internet is available on campus, the school closes at 4:00 pm and few students have access off-campus for research or further self-guided, web-based learning. The library on campus does not lend out books, therefore any after-school studying relies solely on notes taken during class time. This is particularly challenging for pre-reformed students as their school day does not have free time built in, whereas reformed students have mostly unstructured time slots for directing their own learning (see Table 2). This allows students in the reformed program more time with campus resources.

**General barriers among all students.** Recently, military forces occupied the campus and after they vacated, a mandatory school closure at 4 pm was instituted. Prior to the Covid-19 pandemic and civil violence, students lived on campus and the facilities were open later into the day. The school campus was relocated during the military occupation to a small, temporary building in town, further restricting resources and stability for students. The data from this study, and its applicability to other similar programs, should be viewed with these extenuating circumstances in mind. It is important to note that UCBC is considered a high-quality school, regardless of its apparent limitations. Students are engaged in the community; the school culture holds its staff and students to a high standard and its mission statement is "Being Transformed to Transform."

Table 3.

*Differences in Student Groups. A breakdown of the differences between the student groups in the reformed and pre-reformed programs*

| **Program Feature** | **Reformed program** | **Pre-reformed program** |
|---|---|---|
| Professors | Consistent faculty | Visiting faculty |
| Class schedule | Courses spread over 7 weeks | Intensive courses 1-2 weeks long |
| Regular homework and feedback to students on their learning | Yes | No |
| Textbooks | Provided by faculty | No |
| Required reading and writing assignments | Yes | No |
| Course schedule | Planned prior to academic year | Planned week by week, based on professor availability |

**Schedule of courses during study.** When students reach the second year of their program, they can choose either computer science or electrical engineering as a specialization. L1 students in the computer science stream were enrolled in the programming lab while those in the electrical engineering stream were taking the physics lab during the time of this study, as shown in Figure 1. All L2 students at the time of this study were completing linear algebra. The L3 students joined the L2 after the linear algebra intensive was completed to begin an advanced algebra course.

**Data collection and analysis: Qualitative methods and instruments**

Qualitative methods were used to collect ordinal data on the level of reformed teaching delivered by course instructors using the RTOP assessment tool. Additionally, student science literacy levels were assessed using a rubric developed for this study based on the nine traits of science literacy outlined in Table 1.

**Reformed Teaching Observation Protocol.** To compare the two program's teaching styles, classroom observations of teaching were conducted. Two informally trained research assistants, both of who were graduates of UCBC, used the Reformed Teaching Observation Protocol (RTOP) (Piburn et al., 2000) to assess the instruction provided to each student group. The observations were conducted in one-hour blocks for L0 and L1 lab courses. L0 courses are inquiry-led, and instructors only formally present from the front of the class at the very beginning, spending the rest of the time walking around the class for one-on-one interaction with student groups. One-hour observation periods were also carried out for L1 lab courses as they are only 1 hour in length. The rest of the observations for L1, L2 and L3 took place over a two-hour period with the research assistants observing silently from a desk in the classroom.

The training for the use of the RTOP entailed transcribing the original RTOP into plain English so that non-native English-speaking research assistants could read and understand the text. The researcher then conducted several observations with the research assistants so that the scores could be calibrated. This was done in the L1 physics course, the only course instructed entirely in English. Once the scores were within 5 points of each other, and discussions and further training were completed on nuances and interpretations of the RTOP, the research assistants were allowed to conduct their own observations. Five observations were completed for L0, six for L1 (one of these was a lab course), five for L2 and four for L3. A total of 4 different instructors were observed (two in the reformed and two in the pre-reformed).

**Rubric for measuring scientific literacy.** In order to answer the research question regarding student science literacy, a rubric was developed for this study (see Figure 3) based on the skills outlined in the Test of Scientific Literacy Skills (see Table 1) (Gormally, Brickman & Lutz, 2012).

| | **Rubric for Student artifacts** | | | | | |
|---|---|---|---|---|---|---|
| **Introduction** | Hypothesis listed anywhere? | Hypothesis in Intro? | Hypothesis match experiment? | Hypothesis explicit (insert text) | Hypothesis appropriately presented? | Does the student relate the experiment and question back to a "real life" event or need? |
| **Methods and Procedures** | Is there an exhaustive materials list? | Is there a written procedure? | Are there diagrams or photos of the procedures? | | | |
| **Results** | Are there data tables? | Are the data tables labelled properly (labels and units)? | Are there graphs? | Are the graphs appropriately labelled? | Is the data described in the text? | |
| **Conclusion** | Is there a conclusion based on gathered evidence? | Does the student differentiate between probability and proof? | Does the student accept or reject the hypothesis? | Is the report coherently ordered? | | |

Figure 3. *Science Literacy Rubric. The rubric used to analyze scientific literacy skills in student documents. If the answer to questions is "yes", then the student receives a point. There are 18 possible points. Half points are offered for partial inclusions of components (ie. the data tables have some labels but not all).*

The student artifacts that were available for assessment for this research project were the L1 students' physics course lab reports (see Appendix C). For the pre-reformed program, theses completed by the previous year's applied science graduates were selected and assessed. Both artifacts followed the scientific method structure of asking a research question, stating a hypothesis and prediction and then testing the hypothesis and presenting the findings. The rubric addresses the science literacy exhibited in these artifacts, regardless of whether there is plagiarism.

For the reformed program, two lab report assignments were selected for assessment from the students in the electrical mechanical engineering stream. The lab reports were required assignments for this stream of students during their physics lab course and the subjects of their experiments were the period of a pendulum in motion and terminal velocity. These lab reports were approximately 1900 words in length and were a means for students to learn about formulas and laws through inquiry.

Student thesis projects from final-year students who graduated the year prior to this study were selected as a representative sample of the pre-reformed program. These projects were independent and were approximately 12,000 words in length.

**Data collection and analysis: Quantitative methods and instruments**

Quantitative methods included two multiple-choice tests with discrete numerical value outcomes for each participant. This included a test for mathematical ability and a test for science reasoning ability. Lastly, the percentage of plagiarism in student artifacts was calculated.

**Applied science entrance exam.** New applicants for the reformed applied science program take the Applied Science Entrance Exam (ASEE), a multiple-choice test composed of 50 questions created by the founders of the reformed program. The questions were taken from diagnosticquestions.com, a source of diagnostic questions created using crowdsourced data from a wide network of students and teachers across the USA (Wang et al, 2020). Each question has a correct answer and three or four distractors, which are predictably chosen depending on student numeracy level (ibid). A calculator is not permitted during the test, but students were encouraged to take time to work out the problems on a blank sheet of paper. The founder of the program estimates that the exam aims at middle school to high school level mathematics (see Figure 4 for example). Students entering the reformed program are required to take the ASEE and scores for the applicants from 2021 and 2022 were made available for this study.

49. Quelle est l’expression pour le p´erim`etre de ce rectangle ?


A. $10a$ B. $6a^2$ C. $5a$ D. Plus d’informations sont n´ecessaires

Figure 4**.** *Entrance Exam Example Question. An example question from the exam translated: “Which is the expression for the perimeter of this rectangle?” to illustrate the level of math used in the exam.*

The ASEE was administered to the L2 and L3 students in the same manner as required for applicants to the reformed program: in a proctored room without a time limit to complete. To incentivize the students to take the exam seriously since their admission was not dependent on it, biscuits were offered upon completion (food insecurity is common among the students). The teaching assistant from the reformed program as well as the secretary of the Applied Science Faculty spoke directly to the students to further encourage them to take the exam seriously. Although students were offered the biscuit whether they put effort in or not, three aspects of the activity make it highly likely that they did put effort into the exam. First, they were required to put their names on the exam. This meant that their instructors would have access to their grades even though I explained it would be anonymously reported within the research document. Second, students spent a comparable amount of time completing the exam compared to the applicants who completed it during the entrance exam sitting when stakes were high. Lastly, most students filled more than one page working out the problems, suggesting effort.

Two months into the academic year, the L1 students of the reformed program were administered the 2022 ASEE entrance exam during class time, under the same conditions as the

L2 and L3 students. Although similar in style and difficulty to the one that they completed in 2021, the questions were all different. This allowed exam data to be collected from all four current student groups using the same questions, to get a consistent comparison of skill levels.

Data from the first year of the reformed program's entrance exam (from the students that are now in L1) and data from the current year of the program (those now in L0) were compared to the scores of the L1, L2 and L3. This results in a total of five categories of data available for comparison: all applied science applicant scores from 2021 and 2022 (those who were accepted as well as those who scored below the minimum requirement), scores from current L2 and L3 students, and the scores of the current L1 students.

Importantly, the scores collected and available for analysis from the 2021 and 2022 entrance exams were not anonymous, so comparisons of individual students currently in the second year of the program were possible. These paired scores allowed for a comparison to gauge whether their mathematical ability was improving, and to determine if there is an effect related to the reformed program.

**Lawson Classroom Test of Scientific Reasoning.** To understand students' level of scientific reasoning across the four groups, the LCTSR was administered (Lawson, 1978). Students in the reformed program completed the LCTSR one month into the academic year during class time. The test was proctored by the researcher for the L1 students (N = 19) and by the teaching assistants for the L0 students (N = 17) during regular class hours. The test was translated from English into French for this study, and for the L0 students, the questions were read aloud and explained in detail to avoid any confounding effects from reading comprehension issues. This was necessary for the L0 students which had not received the same formal language lessons, required at UCBC for all students, that the other student groups had throughout their first year. Students were given as long as they needed to complete the exam, averaging around 1.5 hours.

A month after the reformed students completed the LCTSR, the L2 (N=27) and L3 (N=14) students were enlisted to take the exam outside of class time, and were provided with lunch and juice as a token of appreciation and to encourage participation. The exam was administered by a research assistant and the teaching assistant from the L0 program. The students completed the exam in approximately the same amount of time as the reformed students at 1.5 hours.

**Plagiarism checking.** Before assessing the level of science literacy of students' work on lab reports and theses, their documents were checked for plagiarism. This study used a paid, publicly available plagiarism checking service called duplichecker (duplichecker.com). Duplichecker is a web-based software that allows documents up to 25,000 words to be uploaded and then searches across web available sources. Importantly, this program works for both French and English texts.

Once the program was completed for a student document, the portions of text content that were flagged as plagiarised were double-checked. Plagiarism software works by searching billions of pages across searchable indexes on the internet, but they are not always accurate in flagging plagiarism. A manual verification ensures that it is not coincidentally similar. This process varied in time, depending on the amount of plagiarism present, but for documents over 10,000 words, at least an hour per paper was required.

L1 student lab reports in the electrical mechanical stream and the computer science stream were selected (2 labs per student except for one, for a total of 34 artifacts). From the pre-reformed program, graduated students' final thesis documents (n = 7) were selected if they were available digitally. The percentage of the document that was plagiarised was calculated for each student paper by dividing the number of plagiarised words by the total number of words, excluding the reference lists, data tables and table of contents. The documents of students in the L1 group were roughly 2000 words in length while the student theses completed by the pre-reformed students varied from 10,000 to 20,000 words in length. The proportions of plagiarism were compared using an unpaired, two-tailed t-test.

## Results

The results section provides both qualitative and quantitative findings. Qualitative methods were used to examine classroom instruction and science literacy levels in students' work, while quantitative methods were used to examine mathematical ability, rates of plagiarism and scientific reasoning ability.

### Applied science entrance exam results

The combined mean scores of all prospective students (including those who were not accepted into the program) from 2021 and 2022 ($M= 55.48$, $SD=18.47$) were statistically significantly higher than the combined averages of all the pre-reformed students of L2 and L3 ($M=45.82$, $SD=15.9$, $t(144)= 3.2$ $p=<0.001$) who were in the first semester of their third and fourth year of the program when they completed the ASEE. The scores of the successful applicants invited into the program in 2021 were retested, and their average scores were compared through a paired t-test as shown in Figures 5 and 6. The scores of each of the 6 groups of test takers are shown as box and whiskers plots to show the variation and means of each group. The highest mean score achieved came from applicants in 2021 and the lowest mean score achieved was from a student in the L2 class. If the L2 and L3 students had been required to earn a 70% on the entrance exam, only 6 of the 55 students would have been permitted to start the program.

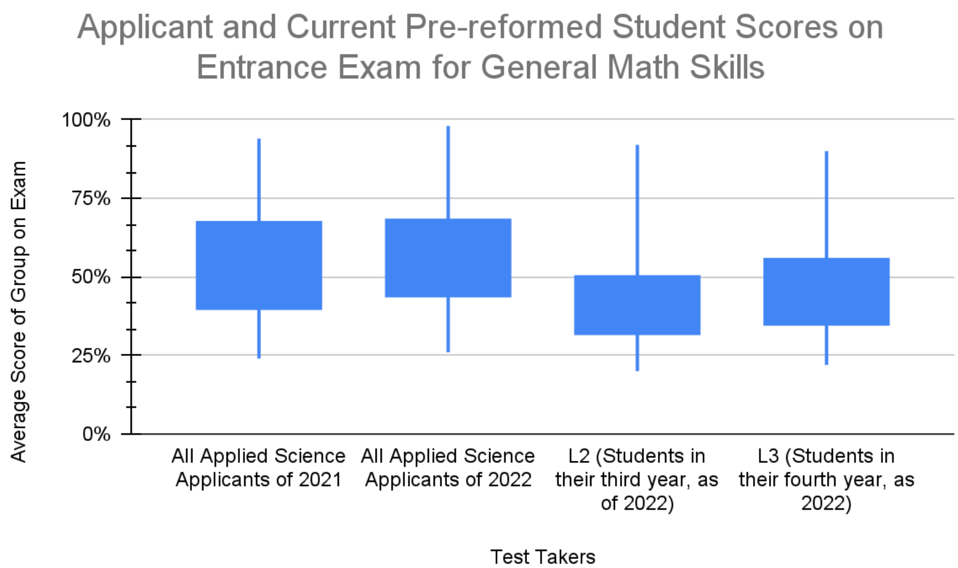



Figure 5. *ASEE Average Scores for Applicants and Pre-reformed Students. Scores for the reformed program's mandatory entrance exam across four groups: all applicants for the new program from 2021 and 2022 as well as the third and fourth-year students in the pre-reformed program. For 2022 n = 46, for 2021 n = 45 for L2 n = 37 and for L3 n = 18.*

Figure 6 shows the scores the L1 students achieved prior to beginning the program and their scores after a year in the program. On average, students currently in L1 achieved a higher score on the ASEE (M = 85, SD = 9.6) than they did the year prior (M = 78, SD = 11.9). This difference of 7% was statistically significant (t(18)=2.1, p = 0.004).

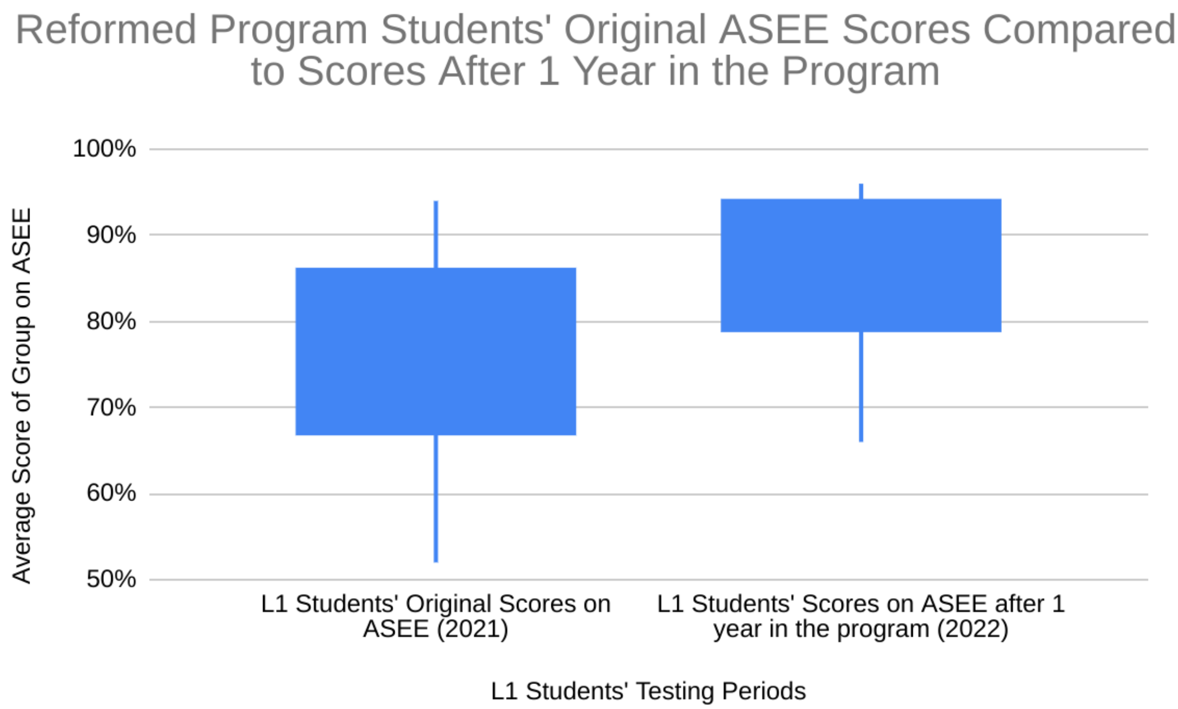



Figure 6. *ASEE Average Scores for L1 Students at Time of Application and After 1 Year. This was a comparison over time, with the same individuals in each group (n=19). The 2022 ASEE was built from questions of similar difficulty, but they were not the same.*

The average time that it took the students in the reformed program to complete the ASEE averaged close to two hours, meaning that students typically spent 2.5 minutes per question with a range of total exam time from 39 - 240 minutes. There was no statistically significant correlation between test scores and time spent on the exam for the L2 and L3 students. For an unofficial comparison, the research assistant for the L1 program was given the test (without having any prior access to it or knowledge of the content) and was able to complete it in 20 minutes missing only one question.

**Lawson Classroom Test of Scientific Reasoning results**

The LCTSR was used to assess the science reasoning skills of L0 students one month into the program, the L1 students one month into their second year, and the L2 and L3 students one month into their third and fourth years, respectively. On average, the scores achieved by the L0 student group on the LCTSR (M = 8.59, SD = 4.61) were not different from the L1 student group (M = 11.24, SD = 3.15), as determined using a two-tailed unpaired t-test of unequal variance (t(33)= 2.03, p = 0.078). The distribution shown in Figure 7, however, shows that some students in L0 scored below 5 while none in L1 scored less than 5.

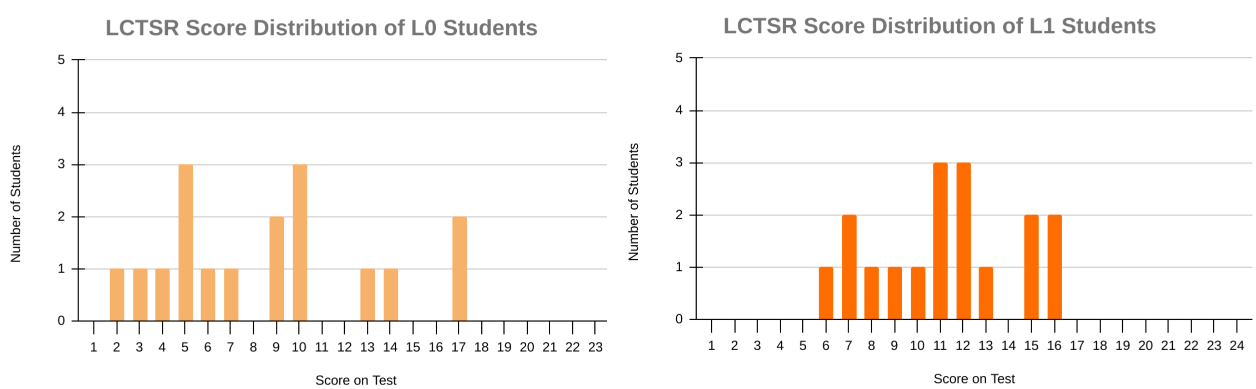



Figure 7. *LCTSR distributions for L0 and L1. Test scores from the L0 (N = 17) and L1 student (N = 17) groups in the reformed applied science program.*

The LCTSR is a multiple-choice test made up of paired question sets that relate to specific types of scientific reasoning, as outlined in Table 4. There was no large difference between student answers from the L0 and L1 except for two pairs of questions focused on probability as shown in Figure 8. At the time this test was administered, L1 students were studying probability and working on homework intended to help develop this reasoning skill.

Table 4.

*Scientific Concept by Question. Comparison of L0 and L1 students on scientific concepts behind each LCTSR question*

| **Scientific Concepts** | **Question Number** |
|---|---|
| Conservation of weight | 1,2 |
| Conservation of displaced volume | 3,4 |
| Proportional thinking | 5,6 |
| Advanced proportional thinking | 7,8 |
| Identification and control of variables | 9,10,11,12 |
| Identification and control of variables with probabilistic thinking | 13,14 |
| **Probabilistic thinking** | **15,16** |
| **Advanced probabilistic thinking** | **17,18** |
| Correlational thinking | 19,20 |
| Hypothetico-deductive thinking | 21,22,23,24 |

A graph of the percentage of students with correct answers for each concept in student groups L0 and L1 can be seen in Figure 8. Students in L0 scored below the average of L1 students for every scientific concept except for “identification and control of variables” but there was no significant overall difference aside from questions 15-18. Students in both groups scored the highest for the first two questions, which focused on conservation of weight and conservation of displaced volume, which is in line with other-first year university students in STEM (Hrouzkova & Richterek, 2021).

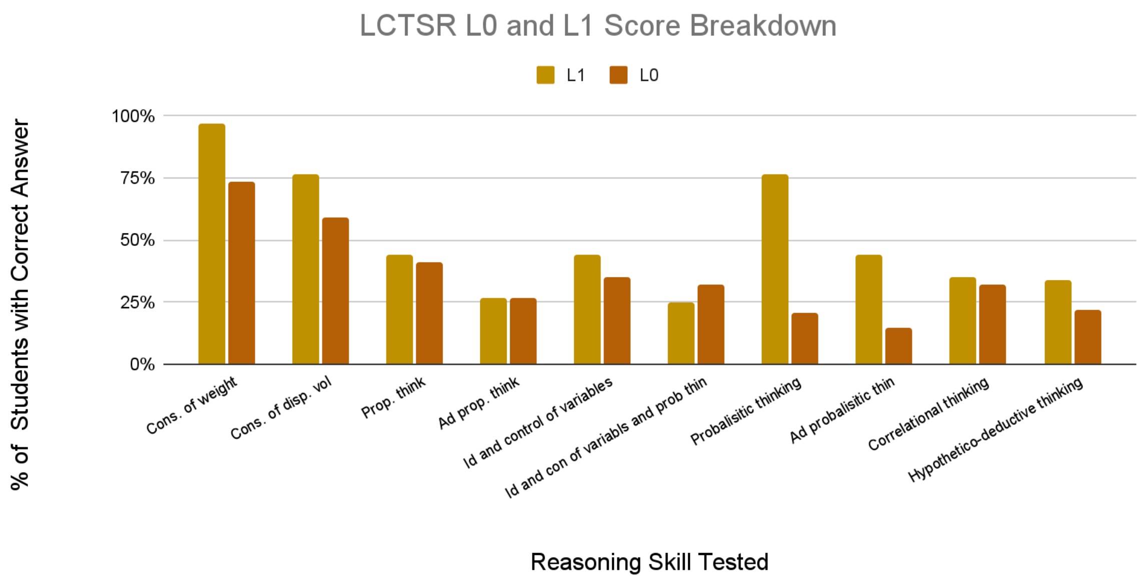



Figure 8. *Percentage of L0 and L1 Students with Correct Answers/Questions. Combined outcomes for each question on the LCTSR compared for L0 (n = 17) and L1 (n = 17) groups. For full titles of reasoning skills see Table 4.*

Like Hrouzkova and Richterek's (2021) findings, 58.2% of the UCBC reformed-program students scored within the "transitional" reasoning stage (Figure 10). Differing from their findings is the proportion of students in the present study classified in the "formal operational" range, in which only two achieved - both L0 students. L2 and L3 students (N = 41) fall mainly within the concrete operational stage (73.17%). Only 1 student scored higher than the transitional threshold (an L2 student).

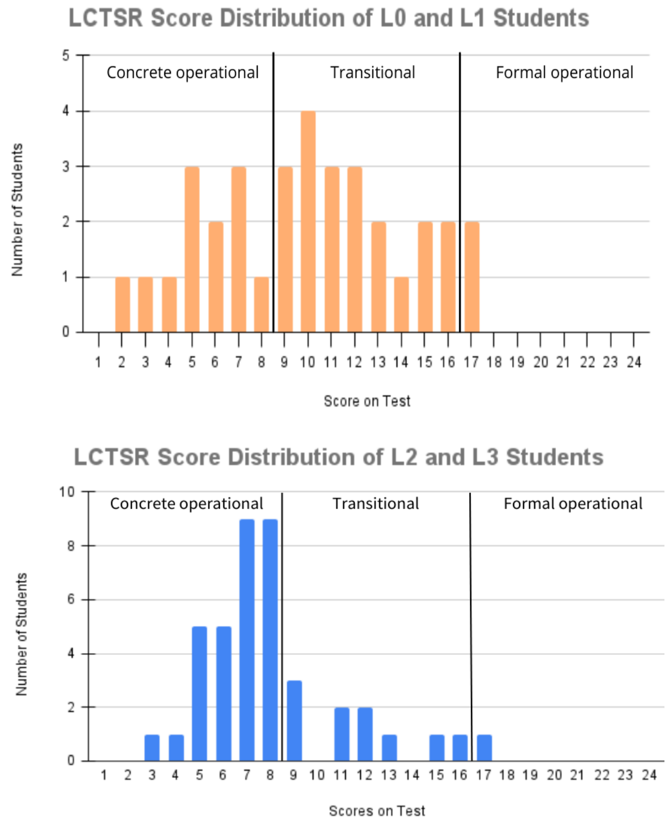



Figure 9. *The Distribution of Student Test Scores on the LCTSR. L0/L1 (top) and L2/L3 (bottom) in relation to the Piagetian stages of cognitive development.*

On average, students in L1 achieved higher scores (M = 11.23, SD = 3.15) than students in L2 and L3 (M = 8.07, SD = 3.12), as determined using a two-tailed unpaired t-test of equal variance (t(40)= 3.51, p = 0.00009). The effect size for this difference is large, with more than 1 standard deviation of the difference between the means (Cohen's d = 1.01). The specific concepts that students in L1 outperformed L2/L3 students on can be viewed in Figure 10.

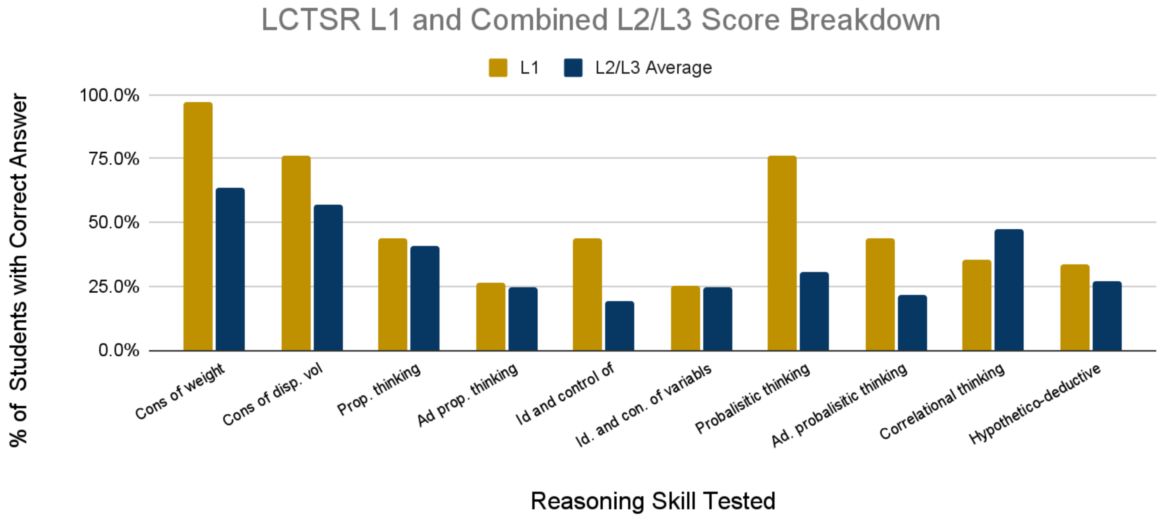



Figure 10. *Comparison of L1 and the Combined L2/L3 Correct Answers/Questions. Combined outcomes for each question on the LCTSR compared for L0 (n = 17) and L1 (n = 17) groups. For full titles of reasoning skills see Table 4.*

**Reformed Teaching Observation Protocol results**

The RTOP provided an inside view of the classroom to answer the research question "are there differences between the curriculum delivery methods and teaching styles of the reformed and pre-reformed programs" (see Figure 11). The overall average shows no differences between the reformed and pre-reformed programs, and the only section of the RTOP in which the reformed program showed higher scores was in Lesson Style. This demonstrates that the teaching used in both programs is similar.

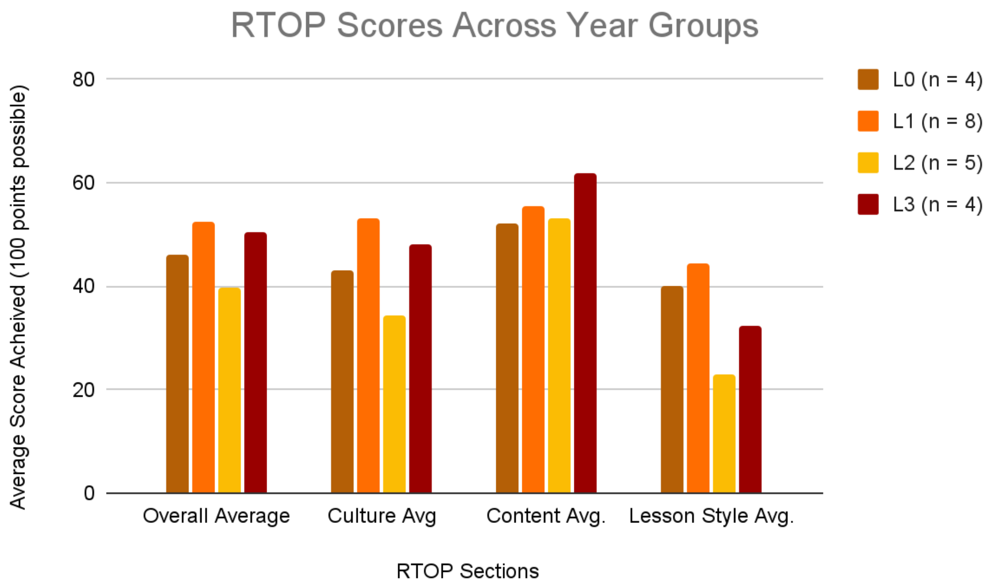



Figure 11. *RTOP Scores Across Groups. The three main categories as well as the overall average score. Observations for L0: n = 4, L1: n = 8, L2: n = 5, L3: n = 4.*

**Plagiarism in student written work**

Table 5 shows the percentage of plagiarism present in student works assessed for the science literacy skill for L1 students in the reformed program. There was one example of a lab report plagiarized more than 25% and one participant plagiarised over 5% of each lab report. The rest of the participants had less than 5% plagiarism with over half of the students having no examples of plagiarism.

Table 5 also displays the plagiarism rates for the pre-reformed student theses. There are two examples which have plagiarism of less than 5%; both of these students were under the supervision of the founder of the reformed program. These students' papers were checked for plagiarism prior to submission and asked to revise and hand in their original work. The plagiarism protocol for the students not under the supervision of the founder of the reformed program is unknown.

Table 5.

*Rates of Plagiarism in Reformed and Pre-reformed artifacts.* Plagiarism rates for L1 students as assessed from lab reports (n = 36) and from thesis documents of graduated pre-reformed students (n=7).

| | **Number of Students with 0% plagiarism** | **Number of Students with >0% - 5% plagiarism** | **Number of Students with >5% - 10% plagiarism** | **Number of Students with >10% - 25% plagiarism** | **Number of Students with >25% plagiarism** |
|---|---|---|---|---|---|
| **L1** | 27 (75%) | 6 (16.7%) | 2 (5.7%) | 0 | 1 (2.8%) |
| **Graduated Pre-reformed student** | 0 | 2 (28.6%)* | 0 | 2 (28.6%) | 3 (42.9%) |

*These students had the founder of the reformed program as their supervisor, who required students to re-do plagiarised work.

**Science literacy in written student work**

An unpaired, two-tailed t-test for unequal variance (t(23)=4.0219, p=0.0005) revealed that the student artifacts for the reformed program had scores significantly higher (M=12.38, SD=3.01) than the graduated student thesis works (M=6.64, SD=3.82) using the rubric shown in Figure 3. Figure 12 illustrates the scores achieved by the student documents for the two sample sets. Only one student document from the reformed student group was assessed as having under 10 points out of 18 possible points. Conversely, the student documents from the pre-reformed student group only had one examined artifact which was assigned a score of over 10 points. For the L1 group, in which there were two documents per student to assess, the scores were within 2 points of each other for every student (apart from one student, who joined the course late).

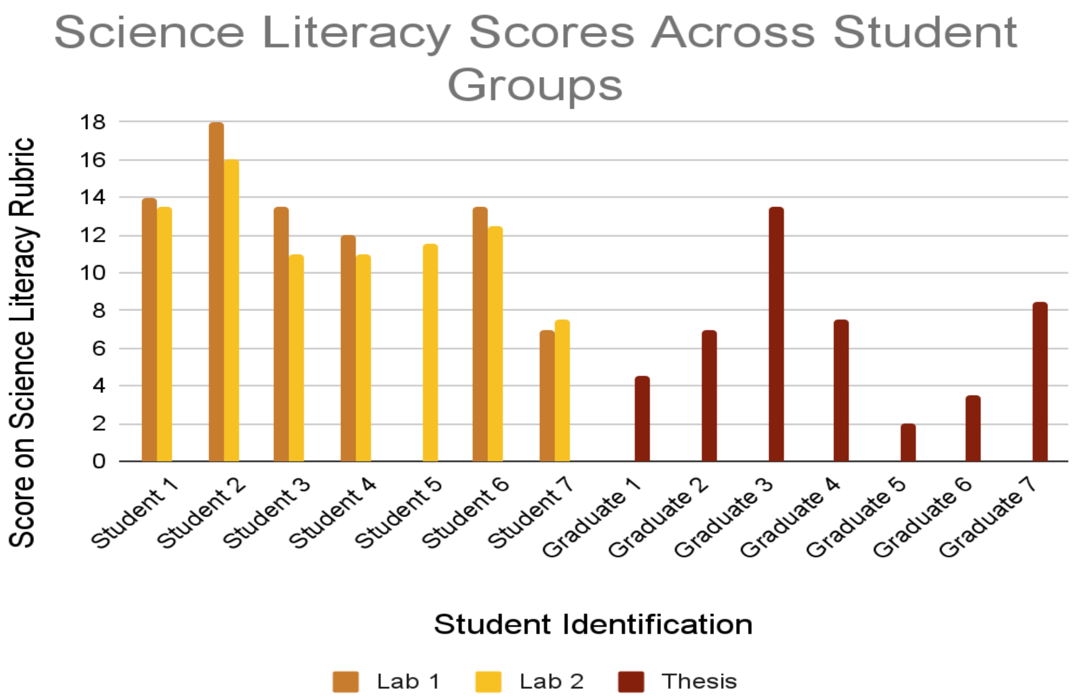



Figure 12. *A Histogram of Scores for Student artifacts Science Literacy. n=13 for reformed student works and n=7 for pre-reformed student works). *Student 5 transferred into the electromechanical stream after the first lab was completed.*

To examine scientific literacy shown in the documents in more detail, Figure 13 shows the proportion of points awarded for the combined reformed and pre-reformed student documents for each question. All student documents for the reformed program were found to have a hypothesis listed in their document. The lowest scoring components for the L1 student lab reports were for an appropriately presented hypothesis and for appropriately labelled graphs. The pre-reformed student documents had no examples of graphs and very few offered data sets or clear conclusions in regards to their hypotheses. Not correctly and coherently testing their hypotheses was the most obvious sign of low levels of science literacy within their documents.

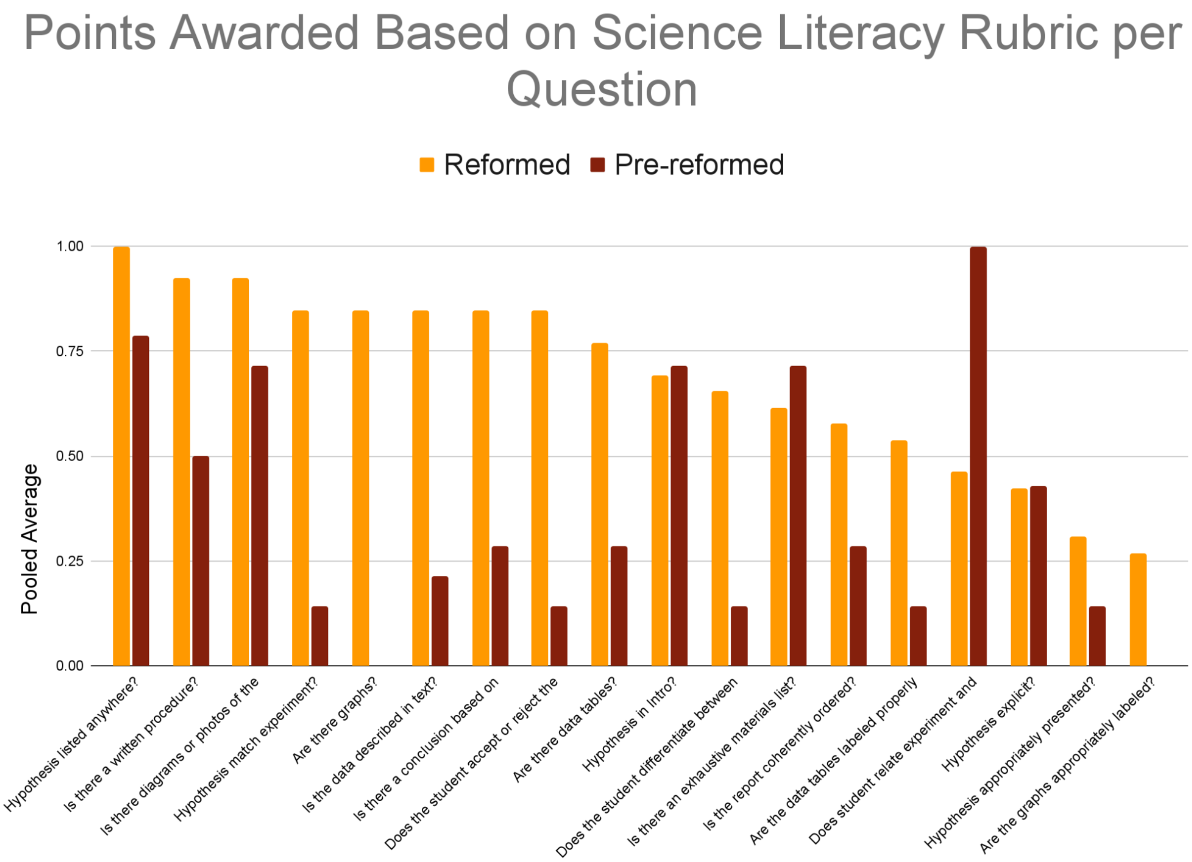



Figure 13. *A Breakdown of the Proportion of Points Achieved per Question on Science Literacy Rubric*. The histogram is organized by highest to lowest combined scores/questions for the L1 student documents.

**Summary**

The classroom culture and content, according to the RTOP, did not differ observably from one program to the other. The teachers in the pre-reformed program scored similarly for reformed practices of teaching, engaging students, asking questions, and keeping the conversation going. The lesson style was slightly more reformed, according to the observations based on this test, for the reformed program as evidenced using the RTOP.

Students in the reformed program showed significant improvement in their mathematical abilities over the course of one year while the pre-reformed students scored below the average of mathematical ability compared to the applicants from the past two years. Their abilities in math remain lower than what is expected of a high school student.

Students in both the reformed and pre-reformed program had fewer students fall into the formal operational category of reasoning than first year university students from other studies (Hrouzkova & Richterek, 2021). All students in the UCBC program scored below the average of a sample of similarly aged students from Hrouzkova and Reichterek's (2021) study, but more students from the reformed science program sit within the transitional reasoning stage.

Students in the reformed program resort to plagiarism less frequently and less extensively than those in the pre-reformed program. Results show that 3 out of 7 (43%) of students in the pre-reformed program had examples of content that was more than 25% plagiarised, while most of the students in the reformed program either had no examples at all or minor incidents of plagiarism apart from two students.

## Discussion

This study sought to compare two applied science programs through quantitative and qualitative research methods to understand how the two programs differed and whether the inquiry-based, reformed program led to improvements in students' learning. Specifically, this study asked how teaching and curriculum delivery methods compared, how student mathematical abilities differed, how rates of plagiarism in student works varied, and lastly, measured students' scientific literacy in each program by assessing written work.

### Reformed Teaching Observation Tool

The level of reformed teaching, as assessed by the Reformed Teaching Observation Protocol (RTOP), revealed that teaching styles did not differ much as far as classroom culture, content and teaching style were concerned. This tool did not account for the lack of resources and structure offered to the pre-reformed students outside of the classroom or their baseline abilities in mathematics and general French and English literacy. This tool was therefore too assumptive in baseline concepts of learning to be an accurate tool in this context and thus represents a major limitation. Aside from this, a surprising outcome is that, at least in this one limited observation period, reformed teaching is occurring with robust student engagement; an integral part of learning (Lord, 1999). The current teaching assistant for the reformed program who is a recent graduate of the pre-reformed program was asked to describe the differences he observed between the two programs:

> *"The teaching style is different in the way that L0 and L1 are studying in a semestrialized program…they can be studying 2 or 3 courses per week. [S]o the teacher has time to give more [homework] and students learn how to manage their time themselves. In the L2 and L3 program students are studying intensively, they are studying one course after another, so the consequence of this is when they will study the tenth course they will already forget the course they have studied at the beginning (they will be studying memorization). This is the big difference between these two programs. According to the resources, the L0 and L1 have more time to do research according to the schedule semestrialized and also opportunities given, now the faculty has a computer lab where students can do their research, both have access to this and also the*

*library…About the attitude, at the beginning the L0 could laugh at the others' promotions because they knew that they were in a different system that looked hard compared to the others. But today their attitudes are the same. They can now discuss as brothers and sisters. Yet the L1 and L0 are working hard because every day they have [homework]... According to me, the current program (L0 and L1) is better than the old program, I have experience in both. I studied in the first and now I'm teaching in the current... This is a discovery for me and I'm happy to be a part of this.” [sic]*

From this former student’s perspective, there are major differences between the two programs, but the tool selected to measure these differences was not as effective at capturing those differences. The RTOP perhaps works well for programs that are implementing a reformed curriculum and helps sort out which teachers are following the reformed curriculum to its fullest potential. This tool was not designed, however, for programs that are highly divergent from typical internationalized institutions. For example, the pre-reformed instructor did not have data or knowledge relating to the low level of numeracy in the students, so even though there was conversation occurring (a trait that grants a high score on the RTOP) the conversation was not leading to learning, because the students lacked the foundational knowledge to build on. Furthermore, it is not known whether the students were engaging with the instructor in a more sociocultural normative way, perhaps asking questions in a way that centred around respect and hierarchy, rather than knowledge construction (Tabulawa, 2013). For this, a culturally appropriate interview method of data collection should be incorporated.

What the RTOP did reveal is that there are talented instructors present in the region who understand the importance of student engagement and creating vibrant classroom environments. It is also true that teaching ability cannot make up for the lack of foundational skills in a group of students in which no baseline requirement was set, and no traceable assessments such as homework assignments with instructor feedback, a log of participation, a file available on their general literacy ability etc. These travelling professors are forced to teach advanced topics with the hope that students are prepared. Perhaps as a final critique, reformed teaching abilities aside, L2 and L3 students were required to rely on memorization as a form of absorbing course content as there were no homework assignments and therefore no opportunities to work with the information on their own time, individually or in groups.

**Applied Science Entrance Examination**

The Applied Science Entrance Examination (ASEE) provided an opportunity to gauge the differences in students' mathematical ability across the two programs, and measure improvement after a year of inquiry-based learning in the reformed program. The results showed that students in L2 and L3 had significantly lower mathematical abilities than the pooled averages of pre-university students from 2021 and 2022. It was also revealed that after a year in the reformed program, students' mathematical abilities significantly improved. This speaks to the veracity of the reformed program's intervention methods. The causation of the improvement in mathematical ability could be due to the reformed program itself, but it may also have to do with the selective process of choosing students that have a higher baseline ability in mathematics. These are variables that differ from the pre-reformed student group as well as the size of the cohorts and therefore the ratio of students to instructors. Additionally, there are aspects of the

ASEE that were not analyzed for this study, including analyzing the student choices of incorrect answers. The ASEE is a diagnostic tool with crowd-sourced data across a large sample of instructors and students, and each wrong answer represents a specific distractor which reveals student reasoning. Therefore, which wrong answers the students selected could be studied comparatively across groups and across a wider sample size of students to glean more knowledge into how the two programs differ with respect to student knowledge.

One suggested cause of these differences is the increased ability for social constructivism to occur through the curriculum and through the increased amounts of unstructured time to work with the information individually and in group settings.

**Lawson's Classroom Test of Scientific Reasoning**

After a year of intervention in the applied science program there was no statistically significant difference in student science reasoning ability, as demonstrated by the LCTSR. It did, however, reveal that on two question sets regarding probability, students in the second year of the program answered correctly significantly more. Keeping the small sample size in mind, the increased ability is likely a reflection of the fact that students in L1 at the time the LCTSR was administered were studying statistics and probability in their physics course.

The fact that students in L1 still achieved greater scores on average than students in L2 and L3 combined indicates an interesting difference between the two programs. This test did not necessarily show the difference in scientific reasoning for the reformed program as an intervention, but it does help to portray how the reformed program's new process of student selection changes the student achievement demographic substantially. Peer-to-peer interactions are an important part of learning based on the social constructivist learning theory, which states that learning occurs through meaningful interactions with instructors and peers (Vygotsky, 1930-

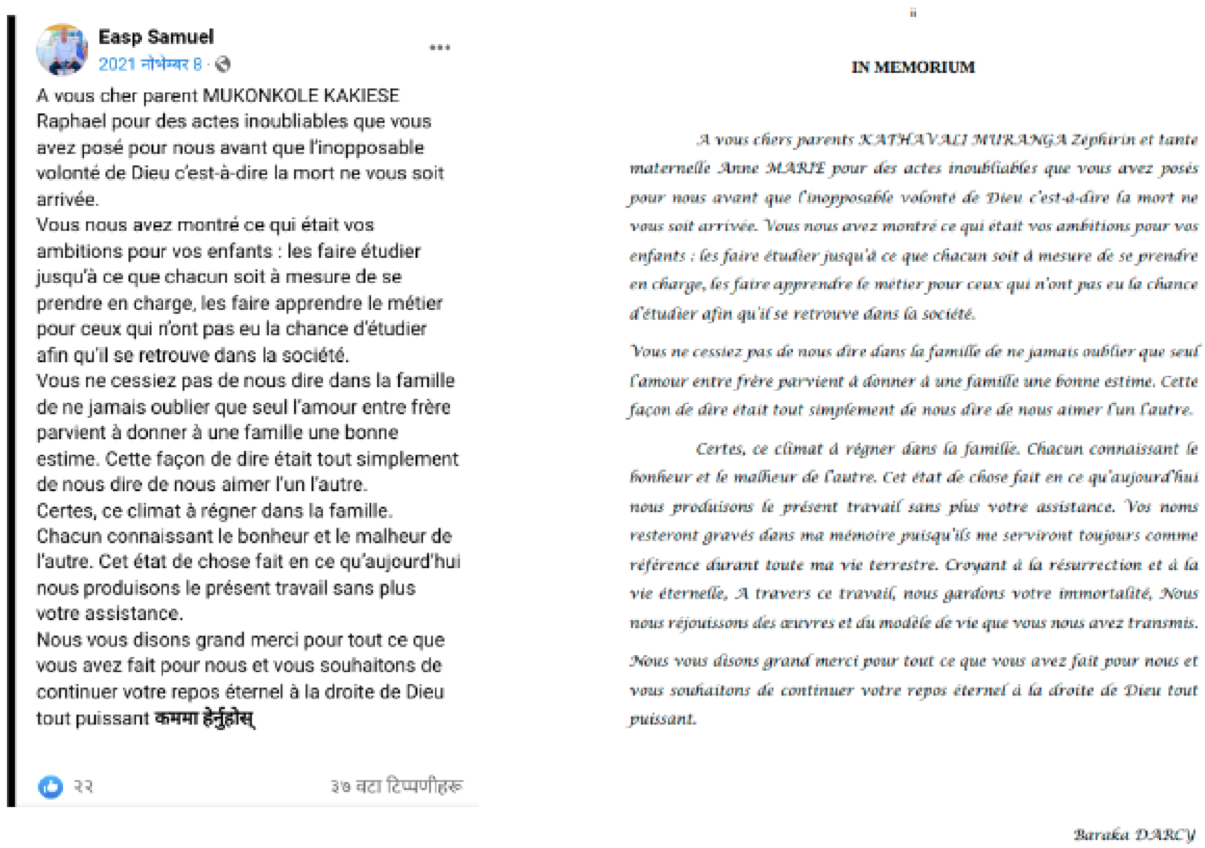
1934/1978). The ASEE has shown that there are many low-achieving students in the pre-reformed program, and it potentially is a self-perpetuating group trait. Low-achieving students, without time or space to work together outside of the classroom, do not have time or the opportunity to construct knowledge. This could potentially explain the skewed distribution of the L2 and L3 student results on the LCTSR. Without time to share ideas and build social networks with one another for academic assignments, progressing to the next level of scientific reasoning is not occurring. In a study by Vaquero and Cebrian (2013), they found that high achieving students tend to form persistent social interactions and a tight-knit group which leads to information cascades, in which a new idea or concept quickly spreads through the social network.

What we see with the distribution of the L0 and L1 LCTSR scores is a group of students with a similar level of reasoning ability to students in other internationalized programs, and the potential for tight-knit groups of high achieving students to occur. The L2 and L3 students fall well below the transitional reasoning category (see Figure 8), have much less time for peer-to-peer interaction during class as well as outside of class time, and have a low level of numeracy. Together these findings suggest that the reformed program has created a learning environment with successful intervention techniques for increasing general knowledge (the ASEE results) and has created the environment necessary for increasing domain-general reasoning skills.

**Plagiarism in student documents**

Plagiarism in student documents was found to be an issue in both the reformed and pre-reformed programs, but the degree to which plagiarism was committed was drastically reduced for students under the instructorship of the founder of the reformed program. As a member of the faculty of Applied Science, the founder of the reformed program advises the senior year thesis students (L3) to help guide them in an independent project. The two students out of the seven sampled were found to have less than 5% of their written content plagiarised, a similar ratio to the L1 student works. This points to students plagiarising not because they are unable to complete a written thesis without plagiarising, but because there are no policies in place to stop them from doing so. It can be said that there is a behavioural difference between the two groups that may be just as important as their science literacy skills.

Although researchers like McCabe (2005) have found that students in the USA commit plagiarism partially out of exasperation with institutions that have inconsistent or weak policies regarding academic dishonesty, and therefore cheat to not be left at a disadvantage, Figure 14 reveals that there may be more going on than simply a desire for fairness. This figure shows an example of plagiarism found within a student's paper from this study for the "dedication" section of their paper - a section that is not technical or topic specific. Interestingly, the Facebook post featured seems to be plagiarised from yet another source. There may be cultural views on plagiarism that internationalized instructors and researchers are completely out of touch with. Whereas it is seen as shameful and lacking integrity in western settings, it may be seen as resourceful and non-problematic for resource-limited HEIs like UCBC.


Easp Samuel
2021 नोभेम्बर 8 ·

A vous cher parent MUKONKOLE KAKIESE Raphael pour des actes inoubliables que vous avez posé pour nous avant que l'inopposable volonté de Dieu c'est-à-dire la mort ne vous soit arrivée.
Vous nous avez montré ce qui était vos ambitions pour vos enfants : les faire étudier jusqu'à ce que chacun soit à mesure de se prendre en charge, les faire apprendre le métier pour ceux qui n'ont pas eu la chance d'étudier afin qu'il se retrouve dans la société.
Vous ne cessiez pas de nous dire dans la famille de ne jamais oublier que seul l'amour entre frère parvient à donner à une famille une bonne estime. Cette façon de dire était tout simplement de nous dire de nous aimer l'un l'autre.
Certes, ce climat à régner dans la famille. Chacun connaissant le bonheur et le malheur de l'autre. Cet état de chose fait en ce qu'aujourd'hui nous produisons le présent travail sans plus votre assistance.
Nous vous disons grand merci pour tout ce que vous avez fait pour nous et vous souhaitons de continuer votre repos éternel à la droite de Dieu tout puissant **कममा हेर्नुहोस्**

२२ ३७ वटा टिप्पणीहरू

ii

**IN MEMORIUM**

*A vous chers parents KATHAVALI MURANGA Zéphirin et tante maternelle Anne MARIE pour des actes inoubliables que vous avez posés pour nous avant que l'inopposable volonté de Dieu c'est-à-dire la mort ne vous soit arrivée. Vous nous avez montré ce qui était vos ambitions pour vos enfants : les faire étudier jusqu'à ce que chacun soit à mesure de se prendre en charge, les faire apprendre le métier pour ceux qui n'ont pas eu la chance d'étudier afin qu'il se retrouve dans la société.*

*Vous ne cessiez pas de nous dire dans la famille de ne jamais oublier que seul l'amour entre frère parvient à donner à une famille une bonne estime. Cette façon de dire était tout simplement de nous dire de nous aimer l'un l'autre.*

*Certes, ce climat à régner dans la famille. Chacun connaissant le bonheur et le malheur de l'autre. Cet état de chose fait en ce qu'aujourd'hui nous produisons le présent travail sans plus votre assistance. Vos noms resteront gravés dans ma mémoire puisqu'ils me serviront toujours comme référence durant toute ma vie terrestre. Croyant à la résurrection et à la vie éternelle, A travers ce travail, nous gardons votre immortalité, Nous nous réjouissons des œuvres et du modèle de vie que vous nous avez transmis.*

*Nous vous disons grand merci pour tout ce que vous avez fait pour nous et vous souhaitons de continuer votre repos éternel à la droite de Dieu tout puissant.*

*Baraka DARCY*

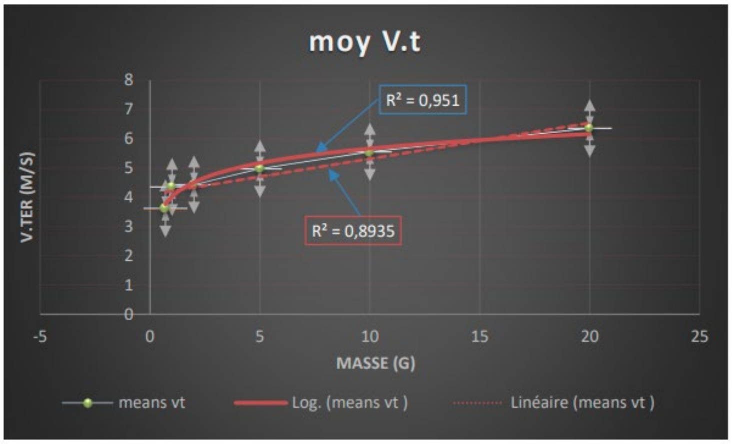
Figure 14. *An Example of Plagiarism in L3 Student Thesis. The Facebook post on the left shows the word-for-word text used by a pre-reformed student in their senior year thesis project, shown on the right. This text exists in other documents published online as well, making its author hard to trace and demonstrating the depth of plagiarism in this setting.*

Students in the L1 program are showing signs of adopting values around academic honesty on their assignments and this can be linked to the structural differences in the program that begins in L0. The bridging year is focused on helping students learn how to learn, and each student is given unique homework sets, requiring that they work independently. This makes copying work from peers impossible and allows for students to begin to construct new understanding of academic honesty and the importance of originality.

Ercegovac and Richardson (2004) note that lessons on academic dishonesty, and building a sense of moral responsibility around the topic, should be introduced throughout a student's life as they progress through the stages of reasoning. Students in settings like the DRC with a weak educational infrastructure may lack a real sense of academic honesty based on their previous school experiences and have to construct this knowledge primarily as students at UCBC.

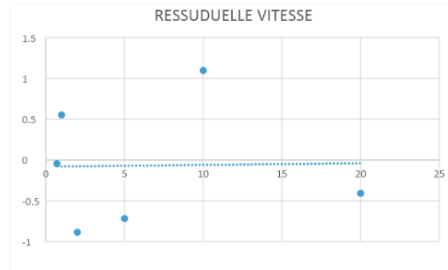
**Scientific literacy**

Science literacy in student documents revealed an interesting difference between the two programs. Perhaps most notable was the ability students in L1 had for organizing and displaying their data through graphs and tables. As seen in Figure 13, no student artifacts from the pre-reformed student theses had graphs present whereas 75% of students in the L1 program artifacts did. Although most L1 students used graphs in their reports, there was a variance in the quality (see Figure 15). The graphs listed in Figure 15 show that the student graph on the left has a higher level of complexity than the second student graph to the right. The left-hand graph has a linear line as well as a logarithmic on, has labels, a legend and the statistical value clearly listed. The second graph is lacking units, has ambiguous lines and not a clear description of what they are trying to demonstrate. From this is can be surmised that students are doing group projects but still working on their reports independently of each other. This adds validity to the rubric which was aimed at assessing individual students' abilities in science literacy.

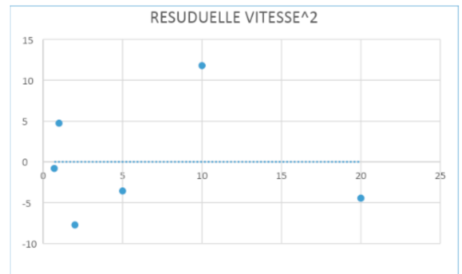



**Graphics 3**

These two graphs (graphics 3 and 4) represent the residuals. The difference between the two is tha
one represents the value of the speed on the square.




**Graphics 4**




After this analysis, we found that the data were inclusive. Because the 2 $R^2$ were the same for both residues.

Figure 15. *Two Examples of Graphs from L1 Lab Reports. The lab activity focused on an object's terminal velocity. These graphs highlight the differences in student ability in science literacy within L1.*

It is important to note that the artifacts selected from the two groups were very different, both in length and objective. This assessment tool was only able to give a big picture look at what students are including and leaving out of their written reports, both of which follow the scientific method. The conclusion that can be drawn from the use of this very simple tool is that there are lots of components missing from the reformed students' artifacts, and the results indicate a low level of scientific literacy. It can also be concluded that most components required for a clear and coherent scientifically literate report for an empirical research project are present in the L1 students.

It is worth bearing in mind that fundamental literacy skills have been shown to be an important component of science literacy (Shaffer, Ferguson & Danero, 2019). Accordingly, the results of this study with respect to scientific literacy are likely influenced by the language skills of the students, as they are unknown and this should be kept in mind.

**Informal observations and feedback collected during the study**

As a final anecdote on the difference that this reformed applied science program embodies, a quote from an alumnus of the program and this study's research assistant is listed below:

> *I've learned so much. Cause, observing Ben's teaching, and other teachers' teaching you may learn many many things. The new pedagogy, the students are centred. So its a student centered teaching. Apart from the first one* [pre-reformed program]*, the teacher is focused on finishing the program. He doesn't care about what the teacher must encourage. But on the other side* [the reformed program] *the teacher is very focused on what the students are learning. That is the biggest difference. Ben's quizzes are totally different. Ben always took time to try to explain what the students have to learn. But the otherside, once the question is on the board, no time is taken. So if you didn't understand, it is over. So, Ben wants the student to succeed. And that is the biggest proclamation for me. But the system we took, you may have a question, you may have a problem, but you don't have the right to ask a question and have them explain more. If you don't have the textbook you are lost. [Dr. Lawson] is totally different. [sic]*

On a different occasion, the research assistant was surprised to see that the founder of the reformed program was visibly upset by the low scores that the L1 students achieved on a Physics quiz. The research assistant explained that he had never witnessed a style of teaching that took student failure as a result of failed teaching.

This research assistant's observations point out the need for a deeper understanding of cultural dynamics at play in the DRC's HEIs. The African higher education researcher, Richard Tabulawa (1997, 2003, 2009, 2013), suggests that non-hierarchical classroom cultures which put learners at the centre are not sustainable in sub-Saharan Africa due to wider societal systems of power that are hierarchical in nature. In other words, classrooms reflect the organisation of the society they are set in; teachers are likely to be looked at as the imparter of knowledge and students should respond but not engage in conversation as equals.

Although this study does not offer data on the sustainability of this program, anecdotes like the ones mentioned above show that the integration of reformed teaching is well-received by those who are given the chance to engage with it and is positive in its impact. Tabulawa's critiques are fair, but until international aid agencies that fund higher education, independent third parties, and the government of the DRC itself can fully assess learning outcomes, the best methods will not be fully known. This research project has attempted to take the first step.

## Conclusion

This research project asked whether a newly reformed applied science program was different from a pre-reformed applied science program at a small HEI in the DRC. It specifically asked if there was a difference in the structure of the programs and investigated this with an observational tool and qualitative evidence gathered and provided by the researcher and the research assistants. The structured observations using the Reformed Teaching Observation Protocol did not reveal any differences between the instructors' methods of teaching or the classroom environment. Unstructured, anecdotal evidence suggests that the relationship between student and instructor, however, was different. Lastly, the observations of the structure of the two programs revealed that students in the reformed program had more agency, more time for personal reflection and self-directed learning and more time working with peers.

The second portion of this study asked if the learning outcomes of the students were different in three areas: mathematical ability, science literacy and reasoning, and rates of plagiarism. The findings from this study show that students in the reformed program have higher mathematical abilities than those in the pre-reformed program and that their abilities improved after a year in the reformed program. Furthermore, students in the reformed program have higher levels of science literacy evident in the written reports of their scientific method-structured assignments and corresponding results and achieved higher scores on the Lawson's Classroom Test of Scientific Reasoning. Lastly, lower rates of plagiarism were found in the reformed students' written works.

In Beni, being a member of the national education community and the international education community are often mutually exclusive. The government demands that certain courses be offered in a degree program whether the institution can provide it effectively or not (see Appendix D for an example of this rigid course guide). To be considered a state-recognized institution these demands must be met and some years ago, this HEI's accreditation was revoked for choosing more evidence-based approaches to instructing and structuring certain programs. To function at an international standard with the resources at hand, substantial deviations from these national requirements had to be taken, including the introduction of an entrance exam for incoming applied science students (forbidden by the government). The irony is that by taking a stand and exempting itself from national rules to achieve greater international standards, the institution runs the risk of losing all legitimacy. A recent graduate informally interviewed during this research project was rejected admission to an institution in the United Kingdom for not having an undergraduate diploma from a government-recognized university. As De Herdt and Titeca (2016) put it, although the government of the DRC itself lacks legitimacy, it is still required to lend legitimacy to educational institutions.

This leaves the question of what rules are more important for a university in the DRC to follow if the outcome means exclusion from the international academic community either way. If international standards are only achievable through the aid and intervention of staff and faculty trained in the ways of the international education community (such as the founder of the HEI, who spent his career at a heavily internationalized university in Nairobi, Kenya) then the university will always be in a precarious state, since these members are apt to use their access to mobility to leave during times of instability. Indeed, since it was founded in 2008, the international staff has ebbed and flowed, and at the time of this research, only one full-time, on-the-ground, international instructor was present.

The reformed program is not widely accepted or welcomed by every member of the Applied Science staff and faculty. Tabulawa (1997, 2003, 2013) points out in his expansive research on the matter, that instructors must be treated in the same manner that students are when expected to adopt new pedagogical methods: as thinking and belief-holding individuals that must construct knowledge before adhering to new models. Instructors of the pre-reformed program struggle to implement new methods of instructing, but the most adamant supporters of the new program are the teaching assistants that have observed the positive impact of the program and been allowed time to construct new ideas about teacher-student relationships and classroom management.

In conclusion, this study has found that students of the reformed program at this HEI are exhibiting improved learning outcomes. Although the sustainability of the program is not known, the unique history of this HEI and its willingness to explore empirically-driven pedagogical methods makes it an ideal subject for continued research.

**Limitations**

A large limitation of this study was that the time frame did not allow for more extensive observations of the instructors in the pre-reformed program. As L0 and L1 students have the same instructors for their entire school year, the L2 and L3 students have perhaps a dozen different instructors throughout theirs. Observing just two instructors may not have been enough to make statements about the overall culture and structure of the instructors and the curriculum of the pre-reformed program. It is also important to note that having many instructors is a more resilient approach to structuring a program than having only a few international instructors that may be asked to leave by the security team during times of unrest. Therefore, it would be more effective to do a longitudinal study of the pre-reformed and the reformed programs to see how things change depending on the circumstances of the setting.

Another limitation was the French and English language literacy levels of all the student participants involved. Rather than assuming students had the same level of literacy, it would have been more appropriate to give each student a diagnostic test to fully understand their levels of general literacy to be able to control for this potentially confounding variable.

Other aspects of this experimental design that limit the strength of the evidence are the small sample sizes of the student groups. As a case study, this research is helpful, but the generalizability of it remains weak.

Lastly, a major limitation of this study was the insecurity of the town of Beni itself. During the 5 weeks that this study took place over, three school days were cancelled due to violence and political protests. This, along with a strict curfew in place for international staff, made planning a robust research design difficult.

**Future research**

There is a great need for research in the field of higher education in least developed countries, in general, and a unique need in the DRC, which fuels the engine of technology in much of the world. This research revealed that there is incentivization from aid organizations to fund education at HEIs, but no assessments on student learning outcomes or institutional policy. Furthermore, it is revealed that learning outcomes and behaviours like plagiarism are affected by interventions of curriculum and academic structure, as shown by the reformed program in this study. More research is needed a) to assess current institutions across the DRC and b) to determine the scalability of this reformed-program for implementation. This future research should be longitudinal and geographically diverse across the DRC.

Lastly, the sustainability of programs such as this should be probed, specifically on the ways in which this type of curriculum intersects with the culture and whether local instructors are equipped to adopt these new techniques.

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# **Appendix A** - UCBC Catalogue LMD, 2016

**6. Faculté des sciences appliquées**

**6.1. Référentiel d'Emploi**

**6.1.1. Génie Informatique**

L'ingénieur Génie Informaticien offre une poly compétence rassemblant différentes qualités. Cet état de poly compétence élargit davantage son champ de débouché professionnel, il peut travailler dans plusieurs domaines selon la spécialité de sa filière en qualité de:

1. **Le Networking**

   a. Analyste et concepteur des systèmes réseaux au sein d'une organisation
   b. Spécialiste en implémentation du réseau informatique physique
   c. Concepteur de protocole de réseaux informatiques et la amélioration ou création de nouveaux algorithmes de transmission de données sur les réseaux hétérogènes.
   d. Administrateur du Réseau informatique
   e. Spécialiste en maintenance Réseau informatique
   f. Spécialiste en Sécurité Réseau
   g. Gestionnaire de Projets d'implantation de Réseau Informatique
   h. Spécialiste dans la programmation réseau.

2. **Le Génie Logiciel et Programmation**

   a. Concepteur des logiciels ou programmes capables de résoudre des problèmes dans la communauté, organisation et industrie
   b. Manageur des projets de construction de logiciel
   c. Programmeur dans une société de production de logiciel
   d. Concepteur des logiciels pilotes des systèmes experts

**6.1.2. Électromécanique**

L'ingénieur électromécanicien offre une poly compétence rassemblant différentes qualités. Cet état de poly compétence élargit davantage son champ de débouché professionnel, il peut ainsi exercer dans les domaines de la production dans l'industrie, le commercial, les bureaux d'étude, la recherche et développement, le management, la gestion des ressources humaines, la fonction publique et l'enseignement.

1. **Énergie et Systèmes**

   a. Concepteur et constructeur des machines transformatrices de l'Énergie.
   b. Gestionnaire des machines transformatrices de l'Énergie.
   c. Mainteneur des équipements ou machines transformatrices de l'Énergie.
   d. Spécialiste en montage et assemblage des équipements de la transformation de l'Énergie.
   e. Spécialiste en transport et distribution de l'énergie.
   f. Innovateur de solutions aux problèmes liés à la production, gestion, transport et distribution de l'énergie.

2. **Chaine de Production**

   a. Technicien de control et suivie de production dans une usine.
   b. Analyste de projets d'implantation de chaine de production.
   c. Concepteur de chaine de transformation de différents produits chimiques ou agricoles.

**6.2. Référentiels des compétences et cours**

**6.2.1. Compétences Générales en Faculté des Sciences Appliquées**

a) **Éducateur**: Éduquer les membres de la communauté à travers les medias par des messages de transformation à l'Image du Christ
   - *Survol de la Bible*
   - *Psychologie générale*
   - *Réalités congolaises*
   - *Santé et protection de l'environnement*

b) **Éthique**: Avoir une éthique, une déontologie professionnelle et un leadership et aptitude de communication qui reflètent les valeurs chrétiennes.
   - *Civisme et éthique*
   - *Éthique Biblique*
   - *Éthique chrétienne du travail et Déontologie professionnelle*

c) **Expertise:** Apporter des compétences dans la résolution des conflits, réconciliation et la cohabitation pacifique dans les groupes sociaux.
   - *Perspectives globales*
   - *Droit industriel*
   - *Anglaise II*
   - *Anglais III*

e) **Capacité d'une réflexion abstraite**: Développer la capacité d'une réflexion abstraite lui amenant à concevoir et modéliser des situations complexes, appliquer et intégrer les connaissances des sciences fondamentales pour répondre aux défis variés de l'ingénierie,
   - *Géométrie analytique*
   - *Géométrie descriptive*
   - *Chimie générale*
   - *Algèbre Linéaire et calcul vectoriel*
   - *Physique générale I*
   - *Physique générale II*
   - *Analyse Mathématique*
   - *Analyse Infinitésimale*
   - *trigonométrie*
   - *Algèbre*
   - *Logique Mathématique*
   - *Mathématiques appliqués*
   - *Les équations différentielles*
   - *Analyse de circuits électriques linéaires.*

f) **Maîtrise et utilisation de l'outil informatique**
   - *Initiation à l'informatique*
   - *Informatique générale*
   - *Informatique appliquée*
   - *Algorithme I et II*

# **Appendix B:** Reformed Program Applied Science Program Objectives for L0

**Research Methods/Computer Literacy**

Outcomes: Students will

- Use basic office/computer applications (word, excel, PowerPoint) to compose, give presentations, and do basic statistical analysis.
- Effectively utilize and cite sources (i.e. books, library, internet) to do research
- Write reports that are clear, thorough, and grammatically correct that offer the student's own insights and synthesis
- Identify reliable and unreliable sources
- Language outcomes: Students will
- Compose multiple page reports using CALP French
- Write short descriptions and summaries (thesis statements) in English using comparative words and language used to give an argument
- Effectively utilize dictionaries, thesauruses, and translation resources

**Foundational Mathematics**

Outcomes: Students will

- Articulate their reasoning in writing and in class discussions
- Form different representations of the same math problems (geometric, algebraic, visual, linguistic)
- Manipulate and utilise mathematical objects and operations. Mathematical objects/operations include variables, numbers, shapes, equations, inequalities, graphs, data.
- Use number sense and pattern recognition to solve problems.

**Inquiry Science**

Outcomes: Students will

- Manipulate an apparatus and accurately take and record a measurement
- Make careful observations
- Control variables and find errors/limitations of an experiment
- Analyze, display, and communicate variables, parameters, and results
- Design experiments
- Make estimations, approximations, inferences, hypotheses
- Verify if results make sense through orders of magnitudes, limiting cases, and dimensional analysis
- Reason by analogy, deductively, through proportions
- Connect physical and abstract representations
- Communicate qualitatively and quantitatively

## **Appendix C:** The Lab Activity Outline for L1 Physics

# Coffee filters

Required analysis tools can be developed in a number of ways. We recommend using Invention Activities (see sqilabs.phas.ubc.ca/invention-activities

### Required analysis tools:

- Quantifying and reducing uncertainty through repeated trials
- Graphing and linearizing data
- Fitting different models to data

### Learning objectives

- Conduct an experiment to evaluate models for describing the drag on and terminal velocity of falling coffee filters
- Propose one or more potential models to investigate and define constraints and criteria for distinguishing between the competing models
- Identify sources of statistical uncertainty, instrumental precision, systematic errors, and possible confounding variables
- Decide what and how much data are to be gathered to produce reliable measurements given set of constraints above, paying consideration to one or several of the relevant variables and controls, the range of measured values, the number of repeated trials, and optimizing signal to noise
- Choose appropriate ways to plot and linearize the data, given the criteria for distinguishing between two models
- Use data and analysis to choose which of a competing set of models is best supported by describing the shape, patterns, and features of data (through appropriate plots or other representations)
- Propose and carry out follow-up investigations or revisions in light of the data and models, especially by devising a modification to the method to improve the reliability of the data or devising a new, complementary experiment for further tests
- Generate a written log of all the decisions made during the experiment including justifications of those decisions
- Provide a clarifying conclusion that appropriately integrates the outcomes of the experiment (especially in the case of revisions and iterations)

## Early: Heavy scaffolding

*Part I – Generating possible models (Think-Pair-Share)*

In this experiment, we will be designing and carrying out experiments to evaluate competing models that describe the motion of coffee filters as they fall towards the ground.

To generate the competing models, first think individually about the different variables that may be involved, what assumptions or approximations could be made to simplify the models, and what confounding variables might exist.

Generating the models allows students to break down the physical system and think about the relevant variables and assumptions. Regardless of what students come up with, the instructor should move the conversation to elicit two competing models: $m \propto v_{terminal}$ or $m \propto v_{terminal}^2$

**Appendix D:** An Example of Government Guidelines for HEI Programs in the DRC

*Réforme Licence Master Doctorat en RDC - Maquettes des programmes de Licence et de Master*

*République Démocratique du Congo*

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET UNIVERSITAIRE (MINESU)

**Commission Permanente des Etudes (CPE)**

ESU

**MAQUETTES DE LICENCE ET DE MASTER**

**DOMAINE DE**

**SCIENCES ET TECHNOLOGIE**

**DOMAINE DE SCIENCES ET TECHNOLOGIE**

*Décembre 2021*



*Réforme Licence Master Doctorat en RDC - Maquettes des programmes de Licence et de Master*

**MAQUETTE CODIFIEE**

| L1 | | | | L2 | | | | L3 | | | | L4 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Semestre 1 | | Semestre 2 | | Semestre 3 | | Semestre 4 | | Semestre 5 | | Semestre 6 | | Semestre 7 | | Semestre 8 | |
| 5 | IFB1111 Informatique et bureautique | 3 | CPG1121 Comptabilité Générale | 4 | AMP1231 Algorithmique et Méthodes de programmation | 4 | PRO1242 Programmation Web-2 | 5 | MDO1351 Modélisation Objet | 4 | STR1361 Supports de Transmission Réseau | 4 | MAL1471 Machine Learning | 3 | DIC1481 Droit Informatique et Cyber-Criminalité |
| 4 | LPR1111 Langage de Programmation-1 | 4 | PRO1121 Programmation Web-1 | 4 | LPO1231 Langages de Programmation Objet | 4 | MAN1241 Méthodes & Analyse Numérique | 3 | GRH1351 Gestion des Ressources Humaines | 4 | MRI1361 Méthodes de Recherche en Informatique | 4 | LPM1471 Langage de programmation Mobile | 2 | DIF1481 Deontologie de l'informaticien |
| 4 | ALG1111 Algorithmique 1 | 3 | DRC1121 Droit civil et législation sociale | 7 | MBD1231 Modélisation et base de données Ec1: Méthode Merise Ec2: Base de Données | 5 | RIF1241 Réseaux Informatiques-1 | 3 | AGT1352 Anglais Technique-3 | 4 | ENT1361 Entreprenariat | 4 | GLO1471 Genie Logiciel | 2 | SEF1481 Seminaire Informatique |
| 6 | LTE1111 Langue et techniques d'expressions EC1: Anglais 1 EC2: Français | 4 | AOR1121 Architecture des ordinateurs et réseaux | | | 3 | AGT1241 Anglais Techniques-2 | 5 | TBD1351 Techniques de base de données | 4 | SEI1361 Sécurité Informatique | 5 | RTE1471 Réseaux de Télécommunication | 3 | AIF1481 Audit Informatique |
| | | 7 | PHY1121 Physiques Ec1 : Electricité Ec2 : Electronique | | | | | | | | | | | 10 | PSI1483 Projet Tutoré |

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