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Improving Computer Science Research in Polytechnic Education

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***Abstract*—Globally, research is an important activity in any educational and industrial establishment. In education, research provides the opportunity for knowledge discovery as well as important solutions to scientific problems. In order to make research an important gateway to education, tertiary institutions have to employ innovative strategies and procedures. This paves the way for effective and efficient education, which benefits a country as a whole. Nevertheless, in developing countries, the progress of research in educational establishments is relatively slow in comparison to institutions of higher learning in developed countries. Factors such as appropriate research environments, electronic library (e-library) support and access to important/top journal and conference articles hinder research progress. With a focus on computer science research, this paper discusses how to enhance research in polytechnic education. Specifically, the paper discusses the problems associated with computer science research in Accra Polytechnic, Ghana and suggests methods and recommendations that can be used to improve these problems in order to achieve effective productivity and sustainability.**

***Index Terms*—Accra Polytechnic, Computer Science, Research, Ghana and Tertiary Institutions**

I. Introduction

RESEARCH plays a key role in shaping the world. Through research, we achieve a better understanding of today's most pressing and complex scientific and social issues such as human rights, cultural diversity, climate change and disease prevention [1]. Decision makers, the public, and even researchers themselves, must have confidence on how research is conducted, and the subsequent findings. The benefits of the research enterprise cannot be realized unless the knowledge generated is both accurate and trustworthy [1].

It is evident that for every country to achieve long term economic growth, Research and Development (R&D) has a highly important role to play. The direct effect of R&D can be measured with difficulty because of the lag and real correlation. Therefore, following the real effects of successful product innovations, developments will be more and more important but also difficult because of the rapid technological improvements [2].

Since the establishment of tertiary institutions in Ghana, research has played a key role in the development of staff, students and the country as a whole. Without research certain developmental goals would not have been achieved. The ability to search and acquire knowledge in a particular discipline so as to use the knowledge to solve problem(s) benefits a nation tremendously. However, in comparison to developing countries, the progress of research activities in tertiary institutions in Ghana is relatively slow and not adequate enough. Consequently, there is the need to improve research so that targets pertaining to development agendas and procedures in Ghana can be fully achieved.

The Ghanaian tertiary educational system is mainly made up of two main categories, namely: universities (public and private) and polytechnics (public). In Ghana there are approximately eight (8) and ten (10) public universities and polytechnics respectively.

Among the ten Polytechnics in Ghana, Accra Polytechnic (A-Poly) was the first to be established. A-Poly was initially established as a Technical School in 1949 and later commissioned as Accra Technical Institute in 1957. By the Polytechnic Law of 1992 (PNDC 321), which became fully operational in 1993/94 academic year, A-Poly was elevated to a tertiary status to offer diploma/degree programmes in sciences, arts, business, technology and engineering. As a tertiary institution in Ghana, A-Poly is governed by a Council established by the Polytechnic Act, 2007 (Act 745) [3].

As a focused tertiary institution, in terms of research, A-Poly has: (i) a mandate to provide opportunities for applied research, publication of research findings and skills development, (ii) a vision to be a centre of excellence in research, teaching and practical training and (iii) a mission to provide life-transforming opportunities and experience for students through entrepreneurial skills development and

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research [3].

In line with the above focus, A-Poly recently established a Research and Innovation Centre. The role of the Centre is to provide end-to-end services which facilitate and support all stages of research and innovation development. The Centre also provides support to the Polytechnic's academic staff in their quest for research funding and other relevant issues [3].

Nevertheless, although a lot has been achieved by the newly established Centre, there are still some research challenges that need to be tackled. Using Computer Science (CS) research as a focus and scope, this paper tries to elaborate on how CS research can be improved in A-Poly. The paper initially outlines some problems associated with productive research in CS and then elaborates on some important factors that have to be considered when enhancing CS research. This paper is significant and justified as it contributes to revealing relevant issues of CS research in Polytechnic Education in Ghana and suggesting methods and recommendations that can make such research more sustainable, beneficial and effective.

A. Motivation

It is very important to appreciate the value of research. The level of research value in an educational establishment paves the way for research motivation concerning its employees and academic staff members. Research is usually viewed along the time axis: short term - 1 year, medium term: 2-5 years and long term: > 5 years.

The value of short term research is the immediate application of knowledge to real-world problems. The value of medium term research is the development and improvement of new methods. The value of long term research is the discovery of new knowledge. Consequently, tertiary institutions have to aim at embarking on long term research to discover new knowledge. In an institution such as A-Poly, such an innovation will pave the way for new knowledge to be discovered in the CS discipline.

Compared with developing countries, CS research in Ghana and some countries in the African continent currently lags behind due to a number of factors such as: (i) unavailability of research funds for certain CS research activities, (ii) Minimized CS research integrity and environments, (iii) lack of e-library support pertaining to important and top CS journal articles, books and conference papers and (iv) insufficient conference organizations and expertise consultation pertaining to CS research.

In relation to CS research in A-Poly, the above listed factors hinder its progress and therefore have to be tackled. Consequently, the motivation of this paper is to suggest ways of improving CS research in A-Poly. The progress of CS research in A-Poly will pave the way for economic development in Ghana in terms of Information and Communication Technology (ICT) and other important areas such as economics and finance.

Due to lack of expertise, most CS researchers in Ghana have to travel outside the country to pursue research programmes in various institutions of higher learning. Additionally, the lack of getting access to very important and top CS journal and conference papers make it very difficult to embark on effective and sustainable research. Inspired by the factors mentioned above, this paper tries to outline various methods and procedures that will enhance CS research in A-Poly.

The rest of the paper is organized as follows: A review of literature is presented in Section II. Section III presents a discussion on how to enhance CS research in polytechnic education. Section IV elaborates on research discussion and Section V finally concludes the paper with some recommendations and outlines some future work.

II. Literature Review

This section of the paper reviews relevant literature pertaining to the subject matter. Initially, the meaning of CS research is reviewed. Then, the next review elaborates on the trends of CS research and finally a brief description of the research methodologies in CS is presented.

A. What is CS Research?

Research is defined as a studious, careful and diligent search inquiry or examination pertaining to a particular field. Research involves the collection of information about a particular subject and usually consists of: (i) investigation or experimentation aimed at discovering and interpreting facts, (ii) revision of accepted theories or laws in the light of new facts and (ii) practical application of such new or revised theories or laws. Fig. 1 illustrates some fundamental procedures in CS research.

CS is the systematic study of the feasibility, structure, expression, and automation of the methodical processes (or algorithms) that underlie the attainment, representation, processing, storage, communication of, and access to information, whether such information is encoded in bits and bytes in a computer memory or transcribed in genes and protein structures in a human cell. The fundamental question underlying all of computing is: *what computational processes can be efficiently automated and implemented*? [4].

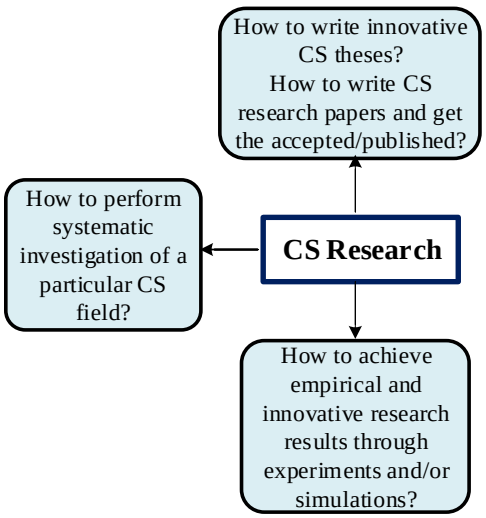

Fig. 1. Fundamental Procedures in CS Research

To tackle this seemingly simple question, computer scientists and researchers work in many complementary areas. They study and research on the very nature of computing to determine which problems are (or are not) computable. Additionally, they compare various algorithms to determine if they provide a correct and efficient solution to a concrete problem. Furthermore, computer scientists and researchers design programming languages to enable the specification and expression of such algorithms. They also design, evaluate, and build computer systems that can efficiently execute such specifications. Finally, they apply such algorithms to important application domains [4].

As a research discipline, CS has always struggled with its identity. On one hand, it is a field deeply rooted in mathematics which has resulted in strong theories. On another hand, it is a field deeply rooted in engineering which has resulted in machines that have completely changed our society. Consequently, CS has inherited its research methods from the same disciplines, involving (i) the mathematical approach with axioms, postulates and proofs and (ii) the engineering approach with quantification, measurements and comparison [5].

B. Trends in CS Research

CS is a growing research field driven by emerging application domains and improving hardware and software that eradicate old bottlenecks even as they create new challenges and opportunities for CS research. Accordingly, the number of scholarly/research papers published in CS conferences and journals has been increasing rapidly for the past two decades. With growing emphasis on externally funded research in most universities, scientific research is increasingly influenced by funding opportunities [6].

Although many funded programs are developed in close collaboration with leading researchers, Hoonlor *et al.* [6] identified more precise relationships between funding and publications related to new topics. According to Hoonlor *et al.* [6], trend analysis has long been researched and applied to many types of datasets, from stock markets [7] to medicine [8] to weather [9]. Additionally, many publications track research trends, analyze the impact of a particular paper on the development of a field or topic, and study the relationships between different research fields [6].

For instance, since 1900, the Web of Science [10] has collected data on nearly 50 million publications in numerous scientific disciplines and examined it at various levels of detail by verifying the overall trends and patterns of emerging fields of research and the impact of individual papers on related research areas [6]. Over the past decade, apart from the Web of Science, studies have also investigated the overlap and evolution of social communities around a field or a topic. For example, Porter and Rafols [11] analyzed citation information to discover evidence of collaboration across fields in scientific research. Other examples are women's authorship of CS publications in the ACM digital library [12] and network models for studying the structure of social science collaboration network [13].

CS research continues to experience continuous and fundamental transformation. For instance, in the past two decades, new topics have arisen within the mobile social networking cluster, while some previously popular topics (such as mathematical foundations) have decayed.

Hoonlor *et al.* [6] recently analyzed CS research communities, CS research trends, and relations between awarded grants and changes in CS communities and trends, as well as between research topics. They found out that if an uncommonly high frequency of a specific topic is included in publications, the funding for the topic usually increases. They also analyzed CS researchers and communities, and found out that only a small fraction of authors attribute their work to the same research area for a long time, reflecting an emphasis on novelty (new keywords) and frequent changes in academic research teams.

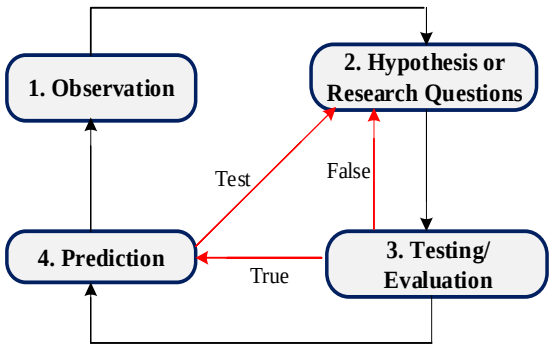

Fig. 2. The Four Stages in CS Research Methods

C. Research Methodologies in CS

A Research Method can be defined as a sequence of steps for systematically analyzing scientific questions; designing and executing research to answer those questions, and producing reproducible results. In CS, a research method is usually articulated scientifically and constantly adds new knowledge and discoveries to various realms and activities.

Some examples of steps in this process include: (i) researching previous studies and current data to pose a question or hypothesis for current research, (ii) designing a research "algorithm" or "protocol" to answer the question, or proving/disproving the hypothesis or research question and (iii) executing the research to create reproducible results. As illustrated in Fig. 2, the four stages of CS research methods include:

- *Observation:* the act of identifying, noting and recognizing a fact or occurrence.
- *Hypothesis:* A tentative assumption made in order to draw out and test/evaluate its logic of empirical consequences.
- *Testing/Evaluation:* The procedure of evaluating the performance of proposed algorithms, models or protocols as a means of analysis.
- *Prediction:* The procedure of verifying and revealing the outcomes of algorithms, models or protocols based on evaluation results and performance.

The first stage of a research involves identifying a specific issue to investigate and develop a specific question to answer. In CS, a hypothesis is usually about whether a proposed approach fits a certain purpose. The goal of CS research is to test different hypotheses. A hypothesis should be clear, specific, and explicit. It is often important to state the limitations of a hypothesis in CS research.

Furthermore, to review critical points of current knowledge including substantive findings as well as theoretical and methodological contributions to a particular topic in the CS field, a literature search/survey has to be conducted. Writing a literature review enables a CS researcher to achieve and demonstrate skills in two areas: (i) information seeking: the ability to peruse the literature efficiently, using manual or computerized methods, to identify a set of useful articles and books and (ii) critical appraisal: the ability to apply principles of analysis to identify unbiased and valid studies.

CS researchers use several methodologies to tackle questions within the discipline. Tasks performed by a single researcher fall within different methodologies. Additionally, the activities required to tackle a single research question may include several of these methodologies [14]. We elaborate on some of these methodologies below:

- *Build Methodology:* A "build" CS research methodology consists of building an artifact - either a physical artifact or a software system - to demonstrate that it is possible. In order for the building of an artifact to be considered as research, the construction of the artifact must be new or it must include new features that have not been demonstrated before in other artifacts [14].
- *Experimental Methodology:* In CS, experimental research methodologies are broadly used to evaluate new solutions for problems. Experimental evaluation is often divided into two phases. In the exploratory phase, a CS researcher embarks on steps and measurements that will help identify what questions should be asked about the system under evaluation. Afterwards, in the evaluation phase, a CS researcher attempts to answer these questions. A well-designed experiment starts with a list of the questions that the experiment is expected to answer [14].
- *Formal Methodology:* In CS, formal methodologies are mostly used to prove facts about algorithms and systems. CS researchers may be interested in the formal specification of a software component in order to allow the automatic verification of an implementation of that component. Alternatively, CS researchers may also be interested in the time or space complexity of an algorithm, or on the correctness or the quality of the solutions generated by an algorithm [14].
- *Process Methodology:* A process methodology is employed to understand the processes used to accomplish tasks in CS. This methodology is mostly used in the areas of Man-Machine Interface and Software Engineering which deal with the way humans build and use computer systems (human-computer interaction). The study of processes may also be used to understand cognition in the field of Artificial Intelligence (AI) [14].
- *Model Methodology:* In CS, the model research methodology involves the description of an abstract model for a real system. This model will be much less complex than the system that it models, and therefore will allow the CS researcher to better understand the system and to use the model to perform experiments that could not be performed in the system itself because of factors such as accessibility and cost. The model methodology is often used in combination with the other four methodologies described above. Experiments based on a model are called simulations. The process of formally describing a model to verify the functionality or correctness of a system is called model checking [14].
- *Quantitative and Qualitative Methodologies:* Quantitative methods in CS research use statistical, formulae and numerical analysis to generate results. The main approaches in quantitative CS research methods include: analysis, casual determination, prediction and generalization of findings [28]. An example of such a method involves the use of survey questionnaires. Contrast to quantitative, qualitative CS research methods employ non-numeric methods such as interviews (face-to-face or distant) [29]. The main approaches in qualitative CS research methods include: discovery, illumination, understanding and extrapolation of similar circumstances. These types of methodologies are usually utilized in CS case study research [30].

III. Enhancing CS Research in Polytechnic Education

The previous sections of the paper have deliberated on how important research is in a tertiary institution. Inspired by five motivating and relevant factors that have to be considered in order to improve research, this section of the paper discusses methods, processes and procedures that can be used to enhance CS research in A-Poly as follows.

A. CS Research Integrity and Environment

According to a report of an expert panel [1], *research integrity* is defined as the intelligible and reliable application of values and principles which are vital to encouraging and achieving excellence in the search for, and dissemination of, knowledge. These values include *honesty*, *fairness*, *trust*, *accountability*, and *openness*.

While a common definition of research integrity is important, it is only one component of fostering an environment of high ethical standards and public trust [1]. Promoting research integrity in Polytechnic Education, specifically A-Poly, requires a concerted effort by all of the major actors: individual researchers/academic staff members of various departments, the management members, the governing council, other public funders and private sector funders.

The CS Department of A-Poly should foster internal department collaborations as well as external collaborations

with other departments to improve CS research. Large groups can be a blessing. They are more resourceful in terms of interaction (now) and networking (in the future). In the CS Department of A-Poly, academic staff should help senior students in terms of research which will enable the senior students to also help junior students in terms of CS research. This pave the way for each colleague to be a teacher and also introduces: (i) experience sharing and encouragements, (ii) more tolerance to mistakes and (iii) more accessibility to CS research.

A positive research integrity and environment is vital for helping CS researchers adhere to honest research practices. It promotes exemplary behavior, fosters public trust and provides a means for developing best practices [1]. Consequently, as shown in Fig. 3, CS research integrity and environment depends on a set of core values and fundamental principles [1]. Additionally, as illustrated in Fig. 3, these key elements can be effectively implemented through three main components, consisting of: promotion, prevention and sanction. We outline these main components in the form of fundamental principles below [1].

- CS/other research activities in A-Poly should be conducted in an honest search for knowledge (*honesty*, *fairness*, *trust* and *openness*).
- Through the Research and Innovation Centre, A-Poly should continuously foster an environment of research integrity, accountability and public trust (*trust* and *accountability*).
- CS/other researchers of A-Poly should know their level of competence and limitations and act accordingly (*honesty*, t*rust* and *accountability*).
- CS/other research activities in A-Poly should avoid conflicts of interest, or if they cannot be avoided, address them in an ethical manner (*trust*, *accountability* and *openness*).
- CS/other researchers in A-Poly as well as the Research and Innovation Centre should use research funds such the Book and Research Allowances (BRA) and/or the National Research Fund (NRF) responsibly (*honesty* and *accountability*).
- CS/other researchers in A-Poly should review the work of others with integrity (*fairness* and *trust*).
- CS/other researchers in A-Poly should report on research in a responsible and timely fashion (*trust* and *openness*)
- Data used for research in A-Poly should be treated with scholarly rigor (*honesty* and *accountability*).
- The management of A-Poly should treat everyone/every staff member involved with research fairly and with respect (*fairness* and *trust*).
- CS/other researchers in A-Poly should acknowledge all contributors and contributions in research (*fairness*, *accountability* and *openness*).
- The Research and Innovation Centre should engage in the responsible training of CS/other researchers (*fairness* and *trust*).

B. E-Library Support for CS Research

E-libraries (digital libraries) are quite new (about 20 years of age) and have been growing at a fast pace. E-libraries have the following characteristics, they: store, distribute, preserve, and protect contents in different formats and, at the same time, they enable interaction between the user and the contents. Furthermore, e-libraries are always present geographically, they can make research work internationally known and they enhance referencing and citations. Additionally, e-libraries can reveal products of an educational process publically and let them be used as inputs for further learning [14], [15].

Globally, libraries have been the keepers and distributors of books, journals, maps and other materials that are used by students in the learning process. Libraries have also been the legal deposit of the products relating to scholarly/research publications i.e. theses and dissertations, articles, technical reports, etc. In general, students have been patrons of the libraries in their institutions [14], [15].

In order to make more learning/study contents available and thus benefit students and faculty, pools of institutions have engaged in commuting items and/or their copies. Consequently, there is no reason why e-libraries should not have the same functions as traditional libraries, except that they can add functions and value due to their digital and networked nature [14], [15]. E-libraries are suitable tools to manage courseware and additional reference items used in the lecture room or classroom. Some reasons for the use/utilization of e-libraries are [14]:

- *Sharing of Contents:* Authors can easily make their contents available for other faculty members to aggregate into their courseware.

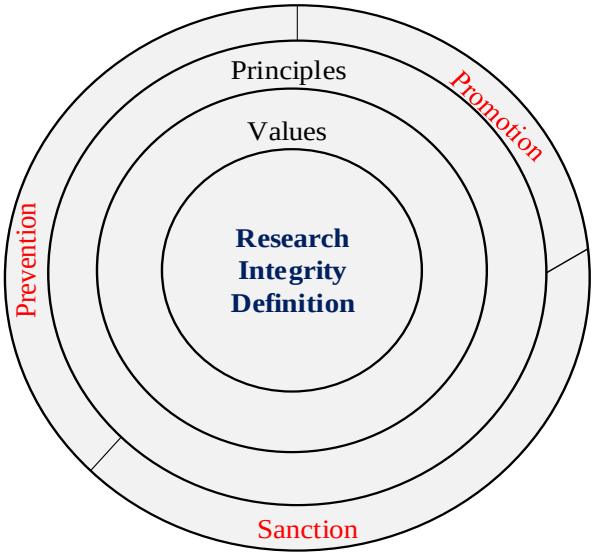

Fig. 3. Elements for a Positive Research Integrity Environment

- *Interactivity:* Contents that are managed by e-libraries can be interactive and based on multimedia. Academic staff members and students can solve exercises and have them checked online, send comments to authors, listen to

soundtracks and view animated images.

- *Document Management:* In e-libraries, documents in all formats – texts, animations, interactive exercises, audio files, video streams, e-books and e-journals can be managed in a unified and effective way.
- *Customization:* Some users of an e-library system may need special features of the contents and the system. This occurs when people with special needs are involved, for instance, persons who are visually impaired or blind. System interfaces and contents in digital formats can be customized to fulfill these necessities.
- *Access Control:* E-Library contents can be assigned different types of access according to the classes of users that are entitled to them. Authors can make a decision on which category of people should have access to their works. For example, students only or the public in general.
- *Cross-institution Co-operation:* E-libraries are generally connected to the Internet. This paves the way for contents be used from different cooperating institutions, as long as the Learning Objects (LOs) are described and managed in a suitable way, thereby enhancing research collaboration.
- *Ubiquitous Research and Learning:* E-Library enables research to be done anytime and anywhere. Since e-libraries are available 24/7 (24 hours a day, 7 days a week) and the Internet connects the whole world, courseware is always available from any geography.
- *Other Reasons:* In addition to the above, e-libraries provide suitable references for research, appropriate scholarly/research publications that are of high repute as well as open access to important/top journals, books and conference proceedings.

As a consequence, the importance of e-library support for CS research in A-Poly is significant and justified. The current e-library system in A-Poly has to be improved to fall in line with the appropriate needs of e-library data and contents regarding CS research. Additionally, the CS Department as well as the Research and Innovation Centre should collaborate with the library to enhance e-library support regarding CS research. Open access to important/top books, journals and conference proceedings is of utmost importance for CS research in A-Poly and thus should be attended to so as to enhance research activities involving CS.

TABLE I
SOME TOP/IMPORTANT ELECTRONIC/DIGITAL LIBRARIES THAT REQUIRE SUBSCRIPTIONS FOR OPEN ACCESS

Electronic/Digital Library	Contents
IEEE Xplore[1]	CS journal articles, conference proceedings, magazines and posters
ACM[2]	CS journal articles, conference proceedings, magazines and posters
Springer[3]	CS journal articles, books and conference proceedings
Elsevier[4]	CS journal articles, books and conference proceedings
Taylor and Francis[5]	CS journal articles
Nature[6]	CS journal articles
Science[7]	CS journal articles
PNAS[8]	CS journal articles
PLOS One[9]	CS journal articles

The utilization of an e-library system regarding CS research is however accompanied with challenges that need to be tackled by A-Poly. Some of these challenges include: interoperability, 24/7 operation, multi-language, multi-culture, multi-legislation situations, multiple types of information, constant change of digital formats, information asset security, digital preservation and Intellectual Property Rights (IPR) [14]. Once these challenges are tackled, there will be the provision of effective e-library support for CS/other research activities in A-Poly.

C. Access to Important and Top CS Digital Libraries

In CS, the Institute of Electrical and Electronics Engineers (IEEE) [16] is an important gateway for enhanced and effective CS research. IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, technology standards as well as professional and educational activities [16].

Another important gateway for enhanced and effective CS research is the Association for Computer Machinery (ACM) [17]. ACM is the world's largest educational and scientific computing society. ACM delivers resources that advance computing as a science and a profession. ACM provides the computing field's premier Digital Library and serves its members and the computing profession with leading-edge publications, conferences and career resources [17].

The use of ICT has changed the informal distribution of reading materials to computer and networked based solutions. The Learning Technology Standards Committee (LTSC) [18], is a committee of the IEEE [16]. As stated on the LTSC web page, their mission is to develop technical standards, recommended practices and guides for software components, tools, technologies and design methods that facilitate the development, deployment, maintenance and interoperation of computer implementations of education and training components and systems. The use of electronic/digital contents in education has become so important that LTSC has one of its working groups with the specific mission of addressing metadata for Learning Objects (LOs) [18].

Due to the important requirements of IEEE and ACM for

[1] http://ieeexplore.ieee.org
[2] http://portal.acm.org/portal.cfm
[3] http://www.springerlink.com
[4] http://www.sciencedirect.com
[5] http://www.tandfonline.com/
[6] http://www.nature.com/nature/
[7] http://www.sciencemag.org/
[8] http://www.pnas.org/
[9] http://www.plosone.org/

CS research, it is important for A-poly to have access to such digital libraries. Nevertheless, access to these digital libraries is restricted/closed and not open generally to the public without e-library supports that have permissions. In addition to good and relevant CS journals, such as this one, other important and top CS journals, books and conference proceedings with reputable abstracting/indexing and suitable Impact Factors (IFs), should be accessible to CS academic staff and students in A-Poly for effective research. Table I shows some important/top CS journals and conference proceedings with high IFs and reputable indexing such as Science Citation Index (SCI) and Engineering Index (EI) which will be beneficial for CS research in A-Poly as well as other relevant tertiary institutions.

As shown in Table I, the listed electronic/digital libraries are of top most priority for effective CS research, especially the first two. As a consequence, to improve CS research in A-Poly, strategic efforts should be embarked on to make subscription to at least the first two electronic/digital libraries in Table I. These efforts would require the CS Department to lease with the Management and Council of A-Poly in consultation with the Ministry of Education (MoE), National Council for Tertiary Education (NCTE) and the Ghana Library Authority (GhLA). The main challenge of A-Poly to gain electronic support for the CS digital libraries listed in Table I is obtaining the funds for subscription. Once the issue of funding can be tackled, the acquisition of CS digital libraries listed in Table I wouldn't be difficult.

D. Organization of CS Conferences and Consultation of CS Experts

In order to enhance CS research in A-Poly, the organization of conferences by the CS Department in consultation with the Research and Innovation Centre is very necessary. Such internal conferences create social awareness [19]-[23] among invited researchers (national or international) and industrial practitioners in the CS filed and foster potential collaborations. As discussed above, this will enhance the research integrity and environment of CS in A-Poly and improve social research and learning among academic staff and students.

Furthermore, as a result of the fact that, the progress of CS research in A-Poly is relatively slow in comparison to other institutions outside Ghana, it is also very necessary that strategic efforts regarding CS consultation with experts within Ghana or abroad are done. This will enable the CS Department in A-Poly to acquire more knowledge in terms of CS research which will promote productivity and sustainability.

E. CS Research Collaboration

Scientific collaboration is often viewed as an asset, so much so that several public policies actively encourage scientific collaboration at both the individual and institutional levels [24]. According to Bozeman and Lee [24], the good reasons for focusing on research involving scientific collaboration is to determine the extent to which and ways in which collaboration contributes to scientific growth and productivity. Most studies of collaboration include an underlying assumption that collaborative activity increases research productivity [24].

As a result of increasing interdisciplinary activities, some research is arguably made much more productive by collaborators bringing special expertise and knowledge, which would otherwise not be available but crucial to research outcomes [24]. In many cases, collaboration is the key process for mentoring students and academic staff researchers. This enhances the productivity of individual scientists in addition to discrete scientific studies [24]-[26]. Notwithstanding these good reasons to expect that scientific collaboration will enhance productivity, the relationship is not patent. According to Bozeman and Lee [24], the fact that researchers and policy-makers *recognize* that collaboration increases productivity does not always make it so. Indeed, there are some arguments

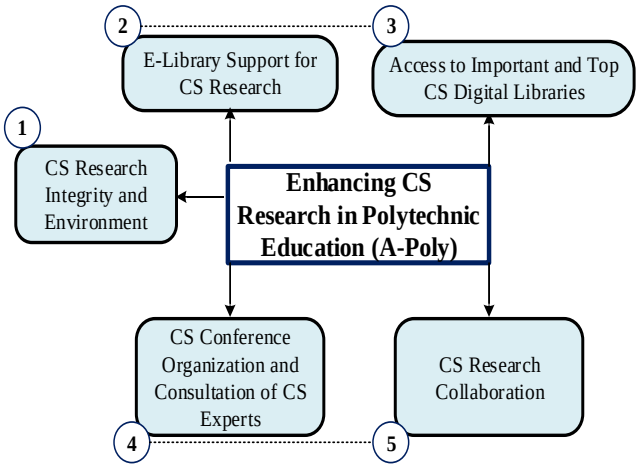

Fig. 4. Factors to be Considered When Enhancing CS Research in Polytechnic Education (A-Poly)

as to why collaboration may destabilize productivity. Most importantly, there are transaction costs associated with working with others.

As a consequence, CS research in A-Poly in collaboration with other institutions in Ghana and outside Ghana is very important for effective research. Such an innovation will enhance CS research and also improve CS education in A-Poly, due to the fact that more knowledge will be acquired by students, academic staff members, the Polytechnic and Ghana as a whole. Nevertheless, strategic efforts should be made to overcome the challenge of transaction cost associated with CS research collaboration. Consequently, it will be more profitable and prudent to start collaborating with other institutions of higher learning in Ghana such as the public universities before making tactical and strategic efforts to collaborate internationally.

IV. Research Discussion

In addition to the literature review in Section II, the previous section of the paper described various methods, processes and procedures that can be used to enhance CS research in A-Poly. These factors are also illustrated in Fig. 4.

The first factor, CS research integrity and environment is of

utmost importance because without positive integrity, the CS research environment in A-Poly wouldn't be suitable for both students and academic staff, thereby undermining learning and training of CS/other programmes/courses in A-Poly.

Furthermore, as shown in Fig. 4, the second and third factors which are related involve e-library support for CS research and access to top CS electronic/digital databases and libraries are also very important. As discussed above the main challenges of these factors is the issue of funding. Nevertheless, for A-Poly to sustain CS research and education, the issue of funding has to be tackled to some extent.

Additionally, as depicted in Fig. 4, the fourth and fifth factors which are also related elaborate on CS research in terms of conference organization, expertise consultation and scientific collaboration. As stated above, these factors will pave the way for enhanced social awareness and also foster potential interactions and collaborations which will eventually improve CS research in A-Poly.

V. Conclusion

This paper presented procedures, methods and processes that can be used to improve CS research in Polytechnic Education. The paper generally discussed CS research literature in relation to its definition, research methodologies and trends. Additionally, the paper presented some very important factors that should be considered by A-Poly to enhance CS research for effective sustainability and productivity in terms of training and learning.

As a future work, this paper recommends that the procedures, processes and methods for enhancing CS research should be implemented/adopted. Additionally, the challenges, for successful implementation, notably funding, should be subsequently tackled to some extent. Furthermore, this paper also recommends that A-Poly should embark on strategic efforts with MoE, NCTE and GhLA to improve CS/other research activities in consultation with the factors discussed.

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