# Astronomy–Focused Engineering LearningParadigm for Different Resource Contexts

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***Abstract*— It is important to increase the number of young persons in technology-oriented careers and disciplines. This is also applicable to the domain of astronomy and space sciences. The existing approach to realizing the intended student stimulation targets young high school leavers and is organized by science voluntary organizations. Such an approach does not consider targeting individuals who are at the point of becoming future engineers. An example of individuals in this group are students in Electrical, Electronic, and Computer Engineering. The existing approach does not stimulate the interests of undergraduate and postgraduate students in astronomy and space sciences. The presented research recognizes that the Electrical, Electronic, and Computer Engineering discipline holds significant content that can be aligned to stimulate student interest in astronomy and space sciences. However, an approach that integrates this multi-disciplinary perspective is required. This research describes an astronomy-themed engineering curriculum for Electrical, Electronics, and Computer Engineering students (undergraduate and postgraduate). It also describes the details of the proposed curriculum and identifies integration points.**

***Keywords – Education, Astronomy, STEM Disciplines, EECE Curriculum, Engineering.***

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## I. INTRODUCTION

The conduct of space sciences is of interest to African nations. The pursuit of space science studies benefits from computing and electronic technology and requires education in computing and engineering sciences. The development of engineers requires providing education in engineering systems. The evaluation of education should reflect in courses being offered at different stages of learning. In the university, courses such as Electrical, Electronics, and Computer Engineering offer an opportunity.

The provisioning of education in a manner that advances space sciences is of benefit to technological and societal development. This is because novel technologies have emerged from space science research [1–4]. Therefore, the provisioning of education in a manner that focuses on stimulating studies in space sciences is beneficial to technological advances. However, the development of learning strategies and their integration into the curriculum in a manner that promotes space sciences is challenging.

The observed challenge arises due to two reasons. First, lecturers and instructors in Electrical, Electronics, and Computer Engineering (EECE) are not necessarily individuals and are interested directly in astronomy research. Secondly, higher education institutions (HEIs) in Africa have access to varying amounts of resources. Third, departments in space sciences (natural sciences) and EECE (engineering) are separated and hosted by different faculties in higher institutions. The provisioning of education in this manner that addresses these challenges is the goal of the research being presented.

The presented research proposes a curriculum aiming to increase students' interest in astronomy. The concerned individuals are undergraduate and postgraduate students studying EECE. EECE is considered because of the increasing role of electronic systems, computing technologies, and data paradigms in the realization of systems being used in astronomy observations. The contributions of the research are:

1. The research proposes the provisioning of Engineering education in a manner that prepares undergraduate and postgraduate students for making contributions to developing systems favoring the conduct of astronomy studies and space sciences. The research presents a multi–perspective approach to Engineering Education. This considers Engineering Education as being required to meet three goals. The first goal is the understanding of the application of scientific principles to Engineering Applications. The second goal is the evaluation of subject matter content with a focus on the usefulness of the concerned content to astronomy. The third goal identifies how the recognized potential usefulness contributes to technological advances.
2. In addition, the research discusses the provisioning of engineering education in different HEI contexts. These contexts are defined by the availability of resources. Three contexts are considered. These are: (1) High Resource Contexts (HRCs), (2) Medium Resource Contexts (MRCs), and (3) Low Resource Contexts (LRCs). The African country is aptly described by the case of MRC and the LRC. In this case, the research being presented discusses how the available technologies are combined with existing facilities to enable university professors to provide education in Electrical, Electronics, and Computer Engineering (EECE). This is done to stimulate students' interest in astronomy and space sciences.
3. The research also presents a framework that enables the integration of the proposed astronomy-themed engineering framework with the internet to provide enriched learning in an HEI for the recognized contexts under consideration.

The research is structured in the following manner: Section II focuses on the astronomy–themed engineering education approach. Section III discusses the provisioning of astronomy–themed education within HEIs considering the context of the MRC and the LRC. Section IV discusses the integration of the emerging framework with the online environment for an HEI in the MRC and LRC contexts. The conclusion is in Section V.

## II. PROPOSED EDUCATION APPROACH

The proposed educational approach is presented in this section. The proposed solution is set in the context of the MRC and LRC seeking to present content in EECE in a manner that increases the awareness of EECE students as regards the challenges arising in space sciences; and how different subjects provide opportunities to engage in technology development for space sciences. The proposed approach focuses on the MRC and LRC. It is recognized that existing work has focused on the relevance of space sciences in non-technical domains [5 – 8].

The rest of the discussion has two aspects. The second aspect presents and identifies how the proposed solution and approach influence education in EECE. This aspect focuses on the identified subject aspects and areas in EECE. The third aspect discusses how the proposed education approach influences novel astronomy aspects and associated roles in curricula integration.

### *A. Identified Subject Aspects and Areas in EECE*

Astronomy is the scientific study of the origins and nature of the planetary system and the universe. This study is done via the design and deployment of systems that acquire radiation for future analysis. Examples of radiation in this regard are gamma and X-ray astronomy; and radio wave (radio astronomy).

The associated rays are acquired by telescope entities. The concerned telescopes host ray detectors and can be located either in space or in the terrestrial environment. From the perspective of Electrical, Electronics, and Computer Engineering (EECE), the design of detectors and telescopes requires education in Electronic technology with a focus on low-noise receiver systems. This aspect of engineering education is being provided within the domain of Electronic Engineering while focusing on realizing high-quality receivers in communication networks [9–11]. The role of highly sensitive receivers in radio astronomy systems has been recognized as seen in [12–14]. The realization of low-noise amplifiers benefits from the use of novel cryogenic cooling in future low-noise amplifiers.

In addition, astronomy also benefits from photography technologies [15–16]. This aspect of photography known as astrophotography has been identified as an area capable of engaging and stimulating increased interest in astronomy [17]. This is because the research in [15–16] has not explicitly identified the role of innovation in engineering curricula in directly enabling the realization of photography technologies.

However, the courses being offered in the EECE curricula do not significantly equip the student with knowledge and skills with a view to participating in astronomy while using and developing photography technologies. In this regard, courses in signal processing and its mathematical foundations (of Fourier transform and analysis) receive significant focus in EECE education.

The aspects of low noise receiver systems involving cryogenic cooling play an important role in designing systems enabling the realization of high-performing systems for future communications. This is seen to be of benefit to next-generation wireless networks [18–19]. The emerging engineering curricula for EECE students can be redesigned to meet this goal. This can be done by incorporating content on cryogenics alongside modules presenting content on radio link design for broadband systems. The research being presented proposes the incorporation of the content on cryogenics. Such an incorporation provides innovation in curriculum aspects relating to aspects on radio link design. This incorporation enables the realization of the goal of providing astronomy-themed EECE-related education. Furthermore, the incorporation of concepts on pixel engineering and computational photography enables the preparation of EECE students. In this case, the identified concepts are incorporated into courses in digital signal processing. This is done with variations in the content adopted at the undergraduate and postgraduate levels.

The discussion of designing an astronomy-themed EECE education has focused on aspects of understanding the role of improved receiver technology. The relation between the aspects of understanding the role of improved receiver technology is also identified. The introduction of low-noise technology with the use of cryogenic technology enables students in Engineering to understand additional engineering concerns.

The introduction of low-noise technology with the use of cryogenic technology enables students in Engineering to understand additional engineering concerns. An important concern is the use of cryogenic technology in data center cooling. The use of cryogenics has been recognized to improve power usage effectiveness (PUE) as seen in [20]. The exploration of understanding the role of cryogenics in this regard is beneficial to enable EECE students to have an enhanced understanding of how thermodynamics influences the computing system operation. This is an important aspect of computer systems engineering.

### B. *Novel Astronomy Aspects and Curricula Integration*

The discussion so far has focused on aspects of astronomy related to the space and terrestrial environment. An equally important domain of astronomy is that of underwater astronomy. Underwater or neutrino astronomy is relatively new compared to terrestrial optical or radio astronomy. A discussion on the development enabling synergies associated with underwater astronomy is presented in [21]. However, a curricula development perspective towards realizing [21] requires further consideration.

The provisioning of EECE education in realizing the solutions presented in [21] requires the integration of blue economy-related concepts into EECE education. This requires the teaching of underwater wireless sensor networks in courses on communication networks and systems. In addition, the discussion in [21] recognizes the area of nascent underwater computing. Nevertheless, it is important to incorporate content on underwater data centers into EECE curricula. The research being presented proposes the incorporation of aspects of the blue economy, ocean science, and underwater systems. In the South African context, the ocean sciences program at Nelson Mandela University. The identified program has a significant focus on postgraduate study. Identification of areas related to astronomy and EECE with a focus on curricula integration outcome is in Table I.

**Table I: Areas Requiring EECE Curricula Integration.**

| Astronomy Context | Integrated Concept | Curricula Outcome |
|---|---|---|
| Astronomy Observations (Astrophotography) | Pixel, Computational Photography | Incorporate Image Processing in Courses related to Electronics, Biomedical Engineering for modules in imaging and digital signal processing and Fourier analysis |
| Receiver Systems (Low Noise) | Improved Communication System Receivers | EECE Courses related to communication networks and systems for undergraduate and postgraduate study. |
| Underwater Astronomy Data Processing | Underwater data centers and computing platforms for neutrino big data processing | Integration of aspects of underwater datacenters as a crucial aspect of cloud computing systems with a focus on advanced undergraduate and postgraduate EECE education. |
| Spectrum Allocation for use in Radio Astronomy (terrestrial) observations | Identification of the radio spectrum portion being required for use by radio astronomy that has a potential conflict with spectrum use as required by wireless networks. | Incorporation of courses on radio spectrum access demands of scientific interests such as radio astronomy in EECE undergraduate and postgraduate courses. |
| Implementing correlator Architecture for Astronomy in the absence or use of minimal hardware via the design and use of software-defined correlators. | Defining the role of correlators with the aim of realizing a software implementation [22]. | Addition of modules on software design structures and architecture for scientific investigations in taught postgraduate courses. |

## III. LEARNING CONTEXTS

The discussion here focuses on designing the astronomy-themed framework for HEIs with MRC and LRC contexts. The discussion does not focus on the case of theHRC. The discussion here is divided into three parts. The first and second develops a framework for the MRC and LRC, respectively. The third discusses the role of external bodies in the proposed framework.

### A. MRC Context

The MRC context focuses on an African country with the capability to allocate moderate resources to astronomy. Examples of suitable countries are South Africa and Namibia. These countries play an important role in providing human and technical leadership in bodies such as the African Astronomical Society (AfAS). In the case of the MRC, instances of the integration cases are presented in Table I.

In this case, the integration directly influences the curricula development stage. The engineering curricula in this case mildly consider the views of astronomy bodies such as the AfAS and astronomers without borders (AWB) [23]. The astronomy bodies such as AfAS and AWB in the case of an MRC interact with curricula developers and professional engineering bodies. In this case, professional engineering bodies at the international, regional, and national levels are involved in the task of curriculum development and modification. The framework being presented proposes increased collaboration between Engineering councils and astronomy-related organizations and research bodies. The case of the MRC involves integration between the Engineering regulatory body and astronomy advocacy organizations. An illustration of the discussed context is presented in Figure 1.

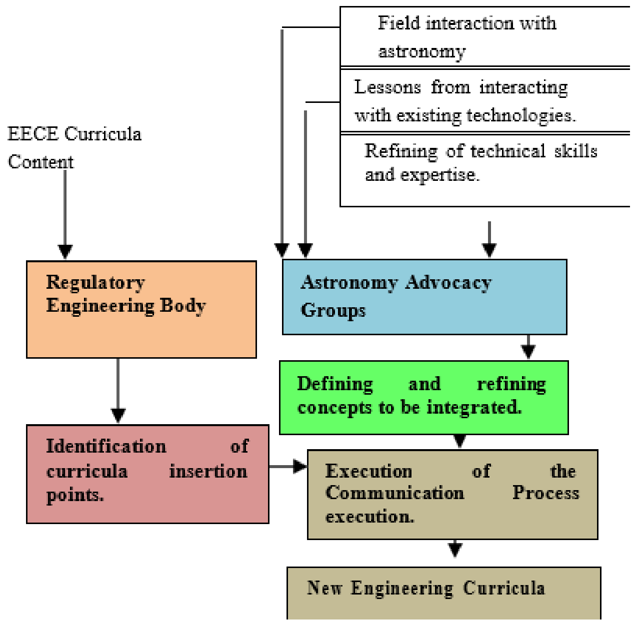



**Figure 1: Process of Formation of Engineering Curricula in the MRC.**

### B. LRC Context

The HEI that is categorized as an LRC has fewer capital resources in comparison to the MRC HEI. In addition, the astronomy advocacy groups are smaller. An example of an astronomy advocacy group in this context is Astronomy without Borders [24]. In this case, the astronomy advocacy group does not directly engage with an Engineering Regulatory Body. Instead, a low-cost communication in comparison to that used in the MRC (shown in Figure I) is adopted. The proposed approach in this case invites submissions from engineering professionals with interests in astronomy research.

These submissions are aggregated into a request for curricular amendment (RFCA) document. The RFCA's scope is for a national domain and comprises mini–RFCA (mRFCA) are valid for the scope of multiple regions within a national scope. The RFCA (comprising mRFCAs) is submitted to a committee of universities, an association of deans in Engineering or a similar leadership association. The scenario in the context of the MRC and LRC describing their paths is presented in Figure 2.

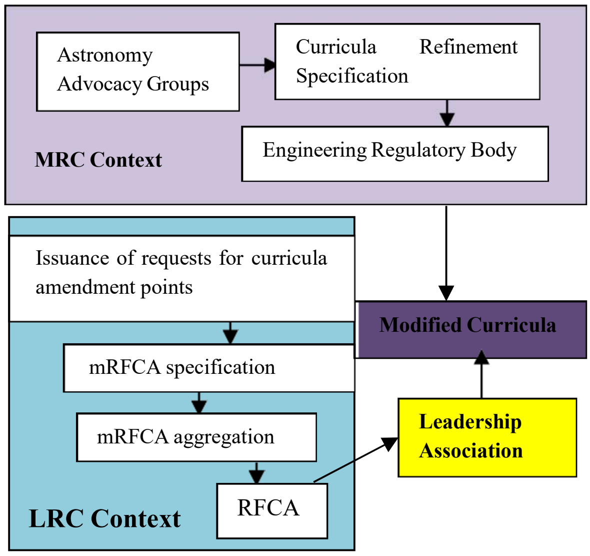



**Figure 2: Process showing modified curricula in MRC and LRC contexts.**

### C. Role of Astronomy Advocacy Groups

Astronomy advocacy groups play an important role in the proposed solution as found suitable in the MRC and LRC contexts. Groups such as the AfAS, AWB and AWB Nigeria generally work with regards to stimulating interest in science, technology related subjects [25–27]. However, the approach presented here differs from the existing approach. The presented solution here aims to achieve the goal of increasing the number of young people in astronomy by engaging with the engineering stream. This is shown in Figure 3.

The path through which an increased number of students is stimulated to study space sciences is presented in Figure 3. Figure 3 has three streams. The three-stream scenario in Figure 3 is associated with the resource-constrained context described by the MRC and LRC. The firststream arises from the case of the existing scheme where outreaches are organized by bodies such as AWB, AWB Nigeria, AfAS, and other STEM-driven education outreaches. The second stream arises due to the use of the proposed approach and is associated with the MRC context. The third stream is incorporated due to the use of the proposed mechanism and is associated with the LRC context. In Figure 3, the approaches used in the MRC and LRC context can be used within the same geographical context by different bodies and organizations.

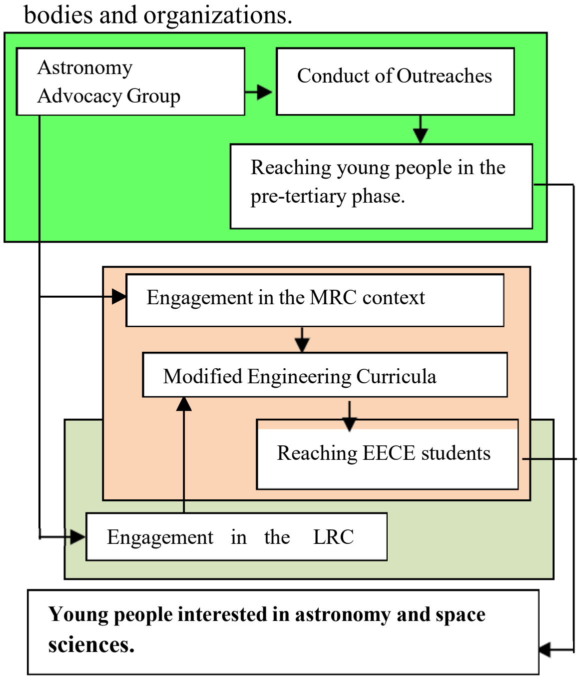


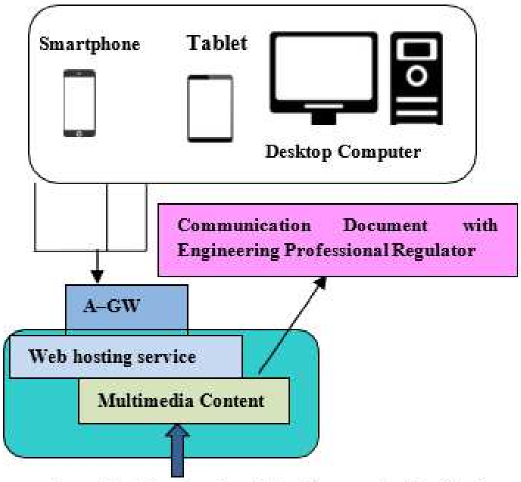

**Figure 3: Increasing student participation in astronomy and space sciences showing existing and proposed scenarios.**

## IV. ONLINE IMPLEMENTATION

The discussion here proposes the implementation of the proposed solution i.e., MRC and LRC context in the online environment. In the case of the MRC context, an online integration and implementation enables the MRC to benefit from the internet. In the case of the MRC, the participating individuals may or may not use sophisticated computing entities. Furthermore, the MRC can afford the costs of internet connectivity and rich web interface i.e., website. Hence,the MRC engages in online related communications at each stage of the data exchange. The online implementation in thiscase involves interaction between multiple devices and web interfaces. In this case, the supported devices are tablets, laptops, desktop computers and smartphones.

The web interface in this case hosts animation and video records developed by the astronomy advocacy groups during engagement with the engineering regulatory body. The MRC context involves the significant use of multimedia content. The concerned multimedia content serves the purpose of explaining how the proposed curricula change adheres to the standards and ethics of EECE education and research. In this case, the MRC can afford the hosting of rich multimedia content. Furthermore, web interfaces and communication approaches incorporate the need to comply with communication standards deemed suitable by the Regulatory Engineering Body.

The communication is shown in Figure 4. The presented scenario shows the role of the advanced gateway (A–GW) in enabling multiple types of devices i.e., mobile phones, tablets, and desktop personal computers to communicate with the web hosting service.




Incorporation of Engineering Regulator Communication Preferences

**Figure 4: Communication Context for the MRC Case.**

In the case of the LRC, the astronomy advocacy group hosts a web portal without multi-media content. The web portal entityis realized via the use of blogspot and social media. The functionality of the web portal s realized without the need to pay hosting costs. In addition, the functionality of an advanced gateway is absent thereby leading to a limitation on the number of devices. Furthermore, the target of the communication process in this case is the leadership academia in the context case. The blogspot provides a platform to host multiple mRFCA that are later aggregated to form an RFCA document. The communication associated with the online scenario is shown in Figure 5.

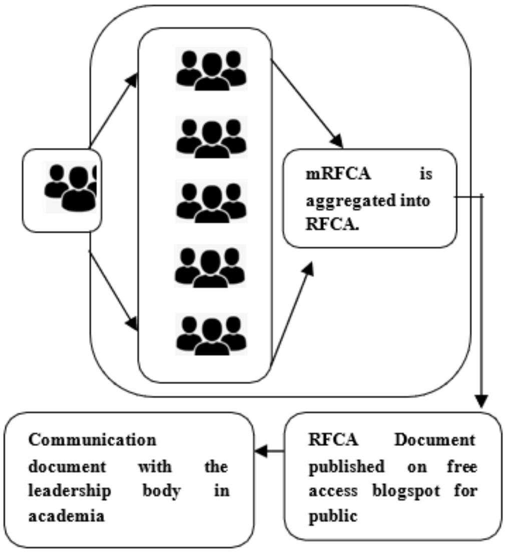



**Figure 5: The realization of mRFCA and RFCA for communications in the LRC context.**

## V. CONCLUSION

The presented research addresses the challenge associated with increasing student interest in space science research. This challenge is addressed in multiple contexts of higher education institutions. The contexts are differentiated by the availability of resources. The paper presents a novel multi-contextual framework aimed at realizingan astronomy-themed engineering curriculum. In addition, the presented research designs an architecture that integrates the proposed solution into the online environment. The integration describes the manner of implementing the proposed solution in an online environment i. Future work aims to assess the suitability of the proposed framework by students inElectrical, Electronic, and Computer Engineering. This will bedone by designing and administering online questionnaires. The future work will also incorporate other Engineering disciplines beyond Electrical, Electronic, and ComputerEngineering in future frameworks. Furthermore, the role of feeder institutions that enhance student exposure to astronomy and space sciences. Furthermore, the use of qualitative research methods will be used to assess the readiness of stakeholders i.e., lecturers and students in higher education institutions to embrace the proposed curriculum approach.

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