Towards the Fourth Industrial Revolution in Namibia: An Undergraduate AI Course Africanized

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***Abstract*—In this Full Paper, we report our experiences of teaching AI in a Namibian university in collaboration with a Finnish university and a few companies. Within the Computing Education Community, only a minority of research reports have experience teaching Artificial Intelligence (AI), and very little research has been conducted on teaching and learning AI in Africa. Given the high importance and impact of AI, this is alarming. Learning and teaching AI in an African higher education setting provides unique challenges compared to the standardized approach in the Global North. Our undergraduate course in AI was carried out in a novel way that emphasized the creative application of AI to meet the requirements of the Fourth Industrial Revolution (4IR). We chose an approach that helps Computer science graduates to explore and get inspired by the opportunities of AI at the ground.**

***Index Terms*—computing education, Africa, AI, 4IR, Robotics**

I. Introduction

Learning and teaching Artificial Intelligence (AI) in an African higher education setting provides unique challenges compared to the standardized approach in the Global North. First, in their strategies, African governments and the African Union expect AI to lead to the much expected Fourth Industrial Revolution that requires a massive increase of AI experts. Secondly, AI is foreseen to make a difference in ordinary people's lives at the grassroots, by improving livelihood and diversifying job markets. Thirdly, the trends of Afrocentrism and Africanization can radically integrate indigenous knowledge systems, the richness of cultures and languages into AI. And last, students expect an AI course to pave the way for the visions, competences and determination of the next generation of Elon Musks.

For instance, approaches in the ACM/IEEE curricula may provide useful viewpoints to AI education, but be inadequate as is in an African setting. Previous research (e.g. [1]) has shown that special characteristics in developing countries may bring a number of additional environment-natural, cultural, and technical issues, which specialists in industrialized countries know little about, and which the standard curricula do not cover well. Only when all the uniquely African challenges are met, we can talk about Africanized AI education – not by localization, reduction or simplification, but contextualization [1], enrichment and diversification.

As collaboration between a Namibian and a Finnish university, a regular fourth year undergraduate course of AI was thoroughly transformed to meet with the African requirements, while recognizing the existing prospectus. The following changes were made. The topics were explicitly related to various opportunities opened by the Fourth Industrial Revolution (like smart countryside, or self-driving cars for disabled students). Students were learning by applying existing AI tools to design solutions for real-life problems on the ground, with users (like IoT-controlled gardening or enhancing education by robotics). Indigenous knowledge systems and representation by the multitude of languages and cultures were related to AI-based knowledge representation. Discussion of future visions and ethics of AI [2]–[4], with the major focus on the African viewpoint, was a critical thread of the course.

Pedagogical principles for the transformation included flipped classroom for increasing student engagement and responsibility, diversifying assessment methods, rethinking the course prerequisites, differentiation of students' individual learning goals, and enlarging the learning community by inviting stakeholders and experts from outside the university.

This paper analyzes the learning process from the triple perspectives of the students, teachers and stakeholders. The exercise is a critical part of a more comprehensive research initiative of Africanized Computing Education.

II. Background

While computing has been practiced since early times, the rapidity with which calculations can be performed today is unprecedented [5]. Digitalisation, computerisation, and the related fourth industrial revolution (4IR) are shaping the world in fundamental ways, raising new classes of challenges, opportunities, and ethical dilemmas [3], [4], [6]–[9]. Indeed, AI may bring a number of benefits to societies and help in tackling complex global challenges [2]. However, AI algorithms can also enhance biases, discriminate, threaten security, manipulate, and nudge behaviour in favour of unknown actors, among other unethical outcomes [2], [10]–[13]. AI algorithms have a big influence on social processes, businesses, decisions, and our perception of ourselves and the surroundings [2]. An example of unethical AI is the Cambridge Analytica scandal and mobile money fraud transactions [6]. However, this far AI and AI ethics has been considered mainly from the viewpoint of the developed and industrialised nations.

The new social and ethical dilemmas brought about by computing and computers—fundamentally different from any dilemmas known before—have resulted in reshaping of AI and AI ethics training in universities [3], [4]. A challenge for the Computer Science Education Research (CSER) community is viewing AI ethics too narrowly inside the epistemological and methodological boundaries of computer science only [4]. It has been argued that technology development, and related CSER, is too often based on a combination of *techno-solutionism* and a shallow socio-technical understanding [4]. Relying strongly on technical expertise with an imbalance between the "technical" and the "social" then results in a lack of means for understanding and therefore addressing societal concerns with technology innovation [4]. A common example is looking at developing countries' challenges too narrowly e.g. within the ICT4D (Information and Communication Technology for Development) research track (e.g. [14]). One challenge is isolating ethical perspectives in standalone AI ethics courses rather than including ethics holistically in CSER curricula [3].

Understanding and solving societal concerns with technology innovation then requires an interdisciplinary effort involving practitioners well-versed in techno-solutionist methodologies, but also in social realities [4]. Indeed, many have recommended the integration of technology and STEM projects with humanities, arts, craft and design [15], [16]. A pedagogical recommendation for CSER is that students tangibly collaborate across disciplines, get introduced to tools to understand and articulate complex and multifaceted problems, and reflect on them and seek solutions [4]. Successful collaborative approaches include using design science research (DSR) in interdisciplinary technology teams [14], and participatory design (PD), which is a collaborative approach of action oriented towards social transformation, with a strong grounding in understanding contextual realities and strengths [17]. DSR and PD have been found especially well suitable in developing country contexts.

Based on understanding the challenges of traditional approaches in teaching AI, as well as decades of experience from CSER in Africa, our pedagogical model is built upon modern pedagogies, such as flipped learning, interdisciplinary understanding, strength-based pedagogy, learning-by-inventing, constructionism [18], [19], grounding with understanding of the local context, co-creation and inclusive technology design.

A. Related research

Africa recognises that AI is a game changer towards its industrial revolution. However, AI education in Africa is still at its infantile stage with less research conducted on its teaching approaches towards a flexible understanding of AI to students. AI is one area that requires an innovative pedagogical approach for easy understanding by students. Perhaps, given the snail pace growth of AI in Africa, many computer science teachers have not yet firmly grasped the knowledge, much less, to devise the best innovative strategy to teach it. While recognising the deficit in research in AI in Africa, African leaders can learn from the Global North by developing policies that will promote technological development by encouraging innovation and investment in AI. Despite the challenges, international funders are recognising the demand to promote AI education in Africa by providing funding through calls. For instance, the International Development Research Center (IDRC) and Swedish International Development Cooperation Agency granted 3.1 million dollars to the African center for Technology studies in Kenyato promote research and teaching of AI/ML education in Africa. This and many other ongoing initiatives require an evidence of more innovative teaching approaches.

Conversely, the Global North, for over the years, has engineered critical approaches to teaching of AI to students due to the perceived 'hard' nature of the subject. The effort by the leading countries in AI has seen quite a number of research detailing the approaches to teaching of AI to students. Freitas and Weingart [20] recognised the difficulty that Computer Science instructors face when teaching AI/ML to non-major computer science students. While recognising this challenge, Freitas and Weingart [20] developed a curriculum covering core concepts, implementation details, limitations, and ethical considerations of AI/ML towards making the teaching of AI/ML in a flexible manner. In teaching AI/ML to students, the researchers delivered a four hour course online due to the COVID-19 pandemic. In each of the lessons, the researchers created non-trivial programming projects that assessed students' abilities to apply AI algorithms to new problems. With this approach, the students were engaged on a hands-on projects during the course. In the outcome of their teaching, the researchers argue that non-computer scientists can comprehend AI/ML concepts without being overwhelmed by the subject material. While we acknowledge the effort in this approach, the researchers did not detail on how the participants (174 students) were grouped during the lecture.

Mills-Tettey et al. [21] collaborated to introduce and teach AI and robotics to undergraduate students in Ghana. The collaborative project was organised by the Ashesi University in Ghana and sponsored by the Carnegie Mellon University in the USA. While the researchers delivered a hands-on but problem-based learning in the course, the design and development of the course module was based on the local resources, the involvement of the local community in the hands-on project, and dissemination skills through teaching. The outcome of the project was successful: students understood the concept and application of AI and robotics. This project aligns with our approach of Africanizing the teaching of AI to and with students in Africa.

In a related approach to teaching AI/ML, Kandlhofer et al. [22] proposed an approach for teaching AI concepts to students at different levels. The new concept encompasses modules for different age groups at different educational levels. However, the modules were developed based on the principles of constructionism [18], where a wide range of hands-on activities were involved in teaching each of the modules. The researchers, from this perspective, believe that compartmentalising students according to their age groups smoothens the teaching of AI. In line with our approach in this study, Kandlhofer et al. [22] employed strategies such as discovery learning, inquiry learning, collaborative learning, problem-based learning, project-based learning, storytelling, peer teaching in teaching AI to the students. In each module of the course, Kandlhofer et al. [22] used platforms such as educational robotics, computer science unplugged, educational games, paper-and-pencil platforms to teach the AI course. Except for the primary school category, the researchers indicated a successful approach in teaching AI where the results indicate that students got a basic understanding of basic AI/computer science topics but had problems to understand the connection between the basic AI concepts and their application in real life.

Analyses of all Computing Education research (CER) papers published in conferences such as ICER and ITiCSE shows that a major portion of CER center around teaching introductory programming, while smaller portions of papers center around other topics, with a significantly small number of research about teaching AI [23], [24]. This is somewhat surprising, as the influence and impact of AI continues to grow. Indeed, teaching and learning AI has received relatively little attention within the CER community. In addition to this paper, very few CER papers report experiences of teaching AI in the African continent, and even fewer if any, of improving AI education by Africanization.

III. Context: Plug-in Campus

The AI course was arranged within the context of Future Technology Lab (FTL), a Finnish plug-in campus in Namibia, which focuses on but is not limited to software engineering education [25]. A plug-in campus refers to a physical extension of a base university, within the premises of a host university, which emphasizes contextual innovation, collaboration and mutual interaction between the base and host universities [25]. In connection with providing software engineering education, the lab organizes varieties of activities from children's design workshops to coding schools [26], seminars and degree programs to individual or peer mentoring [27]. Many of the activities are based on industry-academia collaboration [28].

IV. Approach

This 12 weeks course followed a problem-based learning approach in which students worked on two projects: AI in farming and AI in education. We used the problem-based and project-based approach since the learning objectives also included teamwork, collaboration, creativity, critical thinking, and communication (the four Cs of the 21^{st} century skills). The course included public presentations at the Namibian Scientific Society (NSS) at the middle of the course, several guest lectures, co-drafting a concept paper of Namibia pioneering AI at the grassroots, learning of presentation skills with feedback and review, and team work skills. The breakdown of the course structure is presented in Table I.

The course was attended by 13 students in total of which 9 students were form the University of Namibia and 4 students from the University of Turku. These students were from five different countries: Namibia, Finland, Mozambique, Zambia and Zimbabwe. With regards to course assessment, a range of activities such as demonstrating an AI-based product, reviewing relevant research articles and presentations were given for continuous assessment, which enabled the students to qualify for the final examination.

TABLE I
COURSE STRUCTURE AND LEARNING OBJECTIVES

Learning Session	*Learning Objectives*
Elements of AI MOOC	Get familiar with the basics in AI
Lectures	Understand knowledge representation
Guest lectures	Get inspired by the wide opportunities of AI
Reflections	Become aware of ethical dilemmas of AI
Group Demonstrations	Identify real-life uses of AI
Meet stakeholders	Understand components of intelligent systems
Student presentations	Understand agents and diversity

A. *Guest Lectures*

The course created collaboration with national stakeholders and overseas experts through guest lectures that were held to expose students to how AI can be applied to different real-life challenges. The guest lectures held throughout the course are as unpacked below.

1) AI in Horse Coaching: For this guest lecture, we invited Eeva Nygren, a PhD student at the University of Turku to give a guest lecture on how AI can be applied to horse coaching by monitoring their motions through sensors, which helps in detecting horse limping and imbalance.

2) AI in Digital Art: African art can reach wider global markets by AI-based digitalisation. For this, we invited Dr Tuuli Bell who runs her start-up company, Tuuli Bell Ltd. She gave a guest lecture on the intersection of digital art and artificial intelligence. She introduced the students to digital arts in terms of Non-Fungible Token (NFT) where one can sell and buy art online. NFT uses block chain technologies to create the tokens and make sure that the pictures uploaded are authentic.

3) AI and Ethics: It is important for students to understand what to consider and what not to consider when designing and developing AI systems. For this we invited Mireille Isaro, a PhD student at the University of Turku to talk about the ethics of AI. This enabled the students to think of how they can apply ethics to the AI projects they worked on throughout the course.

4) Machine Learning: For this guest lecture, we had Dr Emmanuel Awuni Kolog from the University of Ghana to give a guest lecture on the application of machine learning by going deep into supervised, unsupervised and reinforcement learning. He further spoke about the overview of the ecosystem of ML.

5) IoT for development: Dr Marco Zennaro introduced the students to the possibilities of Internet of Things for Development (IoT4D).

6) Project prototype presentations: The course also attracted Ms Iina Soiri, the Education and Science Counselor in the Embassy of Finland in Pretoria, South Africa. She was invited to see the project prototype presentations at the Future Tech Lab.

B. Three MOOCs: Elements of AI, Ethics of AI, Build AI

At the beginning of the course, the students were asked to take the free massive open online course (MOOC)[1] built by a company called Reaktor[2] and the University of Helsinki in Finland. The MOOC consists of six chapters with several small assignments: defining AI, introduction to the philosophy of AI, AI in problem solving (search, search and games), basics of probability (the Bayes rule, naive Bayes classification), machine learning (nearest neighbor, regression), to basics in neural networks, and a final chapter on societal implications of AI. The Elements of AI course consists of 25 exercises, which are either automatically assessed or peer-reviewed by other course participants and course instructors. After going through the course, the students were asked to write diaries and reflect on the course from the viewpoint of applying what they had learned in the course projects.

The students were also introduced to the free continuation of the Elements of AI, the Build AI -course[3], which includes 21 exercises, which can be completed on three levels: beginner, intermediate, or advanced, depending on the programming background of the course participant. In addition, students got introduction to the free Ethics of AI MOOC[4], and were encouraged to explore the courses freely and use them for practice and inspiration.

C. Projects and panel discussion

The students worked on real-life projects of which they had first to come up with the project concept plans and later, guided by the concept plan, to develop real project physical prototypes. Apart from various presentations that the students gave in class, the students also gave public presentations at the Namibia Scientific Society (NSS) on their AI in learning and AI in farming projects. The idea behind the presentations was not only for them to make the public aware of how AI can be applied to real-life problems but also to get questions that help them improve their projects and later products. The public presentations were done in two sessions of which the students presented their project concept plans during the first session. Attendees were however skeptical about how the projects were going to workout, with a mixture of phobia and insecurity that AI brings about based on the questions they posed. However after two weeks, the students presented the first project prototypes and the audience got a clear understanding of the projects and the opportunities that come as a result of AI. Both sessions were hybrid as some audience attended physically while some attended virtually via zoom. These presentations contributed to strengthening the collaboration between the two universities, NSS and MindsInAction, a local company that gives robotics training to school children. Figures 1 and 2 are two examples of student projects.

[1]https://www.elementsofai.com
[2]https://www.reaktor.com
[3]https://buildingai.elementsofai.com/
[4]https://ethics-of-ai.mooc.fi/

D. Feedback form

A feedback form was created and shared with the students to share their views on the course activities. Some students filled in the feedback form and they indicated that based on the questions they got from the audience during their public presentations at the Namibian Scientific Society, their projects have lot of potential and they felt that they need funding to take the projects to the next level.

V. Analysis & Results

TABLE II
Summary of course analysis.

Students	groupwork led to open communication publicity sparked motivation physical prototypes enhanced confidence creative sessions inspired diverse results
Teachers	teaching methods for 4Cs confidence in CER for course design
Stakeholders	positive form of collaboration strengthened ties for future collaboration

In the following, the learning processes are analysed from the triple perspectives of the students, teachers and stakeholders. A summary of the analysis is presented in Table II and details are given in the following subsections.

A. Students

From the students' side, several observations were made. First, the groupwork in the course led into open communication. The initial passive communication pattern, typical in many lecture-driven courses, which was typical particularly among online participants, turned into active and open discussions as the course went along. Many open issues were discussed with regards to actual technical coursework, but also for example in regards to groupwork dynamics, e.g. in discussing the fair share of workload among group members in group assignments. Second, the publicity was found to significantly spark motivation. Presentations at the Namibia Scientific Society attracted students to physically attend the event, even from far away. The event was compulsory, but students had the option to attend online. Third, it was found that physical prototypes enhanced self-confidence and thus commitment: several students said that they were inactive in the beginning of the course because they did not believe that their projects would be realized. The first working prototypes changed their opinion and, thus, their commitment. Fourth, creative sessions had impact beyond their origin in team works: a session for co-authoring a concept paper on Namibia as a pioneer in AI at the grassroots inspired students to fast and diverse results.

B. Teachers

According to the observations with regards to the 4Cs of the 21st century skills: creativity, communication, collaboration, critical thinking - these all were boosted according to the observations. The course structure was new as this was a joint course between lecturers and teachers from two different countries. Everyone learned, and the course was a learning experience also for the teachers. In this way, many ideas were gained for future implementation and improvement of computer science courses.

1) The 21st Century Skills: The course was very engaging as it allowed students to engage with each other and with the lecturers and they themselves mentioned that this is very different from almost all the courses they have attended. The project-based course allowed the students to collaborate in solving a real-life problem. The two groups were formed at the very beginning of the course. The group on AI for farming developed a vertical garden. The group on AI for education developed a smart flower. Throughout the course students were able to apply critical thinking, creativity, collaboration and communication. They applied all these skills as they were able to come up with creative projects and apply critical thinking into achieving their goals.

Any course that aims to prepare students to face the unknown future needs to integrate the 4Cs of the 21st century skills [29]. The artificial intelligence course equipped students with these 4Cs (critical thinking, creativity, collaboration and communication) 21st century skills they need to flourish in the globalized world.

In this course students were able to reflect on how AI can be effectively applied to agriculture by designing and developing a vertical garden and to education by developing a smart flower that teaches children colors. They further applied in depth thinking not only through approaching problems from different angles but they were able to analyze, evaluate, critique and interpret how the projects they worked on can impact the communities. It was interesting seeing how the students were thinking in new directions and applying creativity by imagining how the end products can do and look like.

Throughout the AI course, the students were committed to work together within their groups toward a common goal through not only sharing the ideas but also sharing the workload as every member was a assigned a role for everyone to be equally involved. They did not only present their project concepts plan and project prototypes to their lecturers but they also presented to the national and international community through a panel discussion that was held at the Namibia Scientific Society (NSS). It was through this panel discussion that the students were able express themselves by telling the public the projects that they are working on and how the communities benefit from them.

C. Stakeholders

All involved stakeholders reported enthusiasm and interest in the course activities and willingness for future collaboration in further development of computing courses and related educational technologies.

1) Collaborations: This course did not only strengthen the collaboration between the two universities, MindsInAction, a local company which offers robotics classes and the Namibia Scientific Society but it also opened a door for AI threads at NSS. It is also the approach and the projects developed throughout this course that attracted the Namibian university's Office of the External and International Relations to collaborate in funding writing proposals and concepts.

D. Curriculum Reform

The students indicated that the courses in the current curriculum focus more on theory-based lecturing, which involves general skills and are not tailored to integrate the skills that they need to face the real world. They further indicated that it is their first time that they are attending a course that has equipped them with professional development skills to face the real world. The professional skills in teaching and learning can be accomplished through curriculum reform and alight it to the demands of the universal society and global economy. As Bedir [29] argues, it is important for courses to have the 4Cs well defined to make sure the teaching and learning process is preparing the students for the real world.

E. Physical Prototypes of the Projects

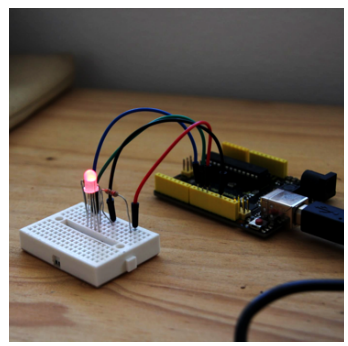

Fig. 1. Student project: Smart flower (AI for Learning)

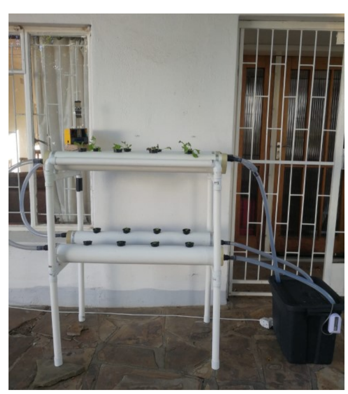

Fig. 2. Student project: Vertical garden (AI for Farming)

1) Vertical Garden Prototype: The vertical garden prototype is a smart way of gardening which uses sensors to monitor the plants and alerts the farmers when water or nutrients are lacking or when there is an intruder. The vertical garden system saves water and space as it pumps water vertically to all the plants in a row. The system has an e-market branch which helps farmers promote their crops and use elements of AI to alert the farmers when the crops are in demand of care. Figure 2 shows a picture of the vertical garden project.

2) Smart Flower Prototype: The smart flower prototype acts an assistant teacher that educates learners on colors. The smart flower is made up of an Arduino board, LEDs, jumper wires and resistors. It has a voice recognition feature that recognizes the learner's voice. The smart flower system teaches the colors by listening to the voice input from the learners and lights the LED with the said color. Figure 1 shows a picture of the smart flower project.

F. Assessments

1) Bonus points: It is important for lectures to involve positive social aspects through open engagement throughout the lectures. At the beginning of the course students were however not really engaging, so the teachers introduced bonus points which a student could gain to contribute to their continuous assessment marks or to their ECTS (European Credit Transfer System) credits after participating in class. There was a rapid increase in students' engagement after that and the vibe never stopped. They started being critical and asking questions frankly and being themselves. This did not only boost their confidence but also prepared them to solve real world problems.

2) Group and individual work: On top of the bonus points, the students were assessed by the group and individual work they were tasked with throughout the course. The group work involved the project concepts plan that they worked together to plan and get a clear idea of how they were going to develop their projects. Group presentations during class and at the panel discussion held at NSS contributed to their Continuous Assessment (CA) marks especially for students from the University of Namibia where CA marks are compulsory for them to qualify for the compulsory examination: one needs 50 percent to qualify. Individual work on the other hand involved a review of a self-selected research paper where students had to familiarize themselves with certain topics before the lectures. In this course, students did not only gain marks but also experienced what they need for real-life work.

3) Compulsory Exam and ECTS: As mentioned earlier, this course was attended by the students from the University of Namibia (UNAM) and University of Turku (UTU). For final assessments, the students from UNAM sat for the compulsory examination which tests them on the content they have learned throughout the semester. The students from UTU on the other were awarded with ECTS credits at the end of the course, by completing a project that replaced the examination.

VI. Discussion

In terms of Computing education research (CER), our results represent a relatively novel stream. This far, the mainstream of CER has focused primarily on identifying research questions of, understanding current approaches and processes in and further improving the practices for learning and teaching as defined and conceptualized by the universal Computing curriculum [23], [24]. Complementary to the conventional interest in CER, we wanted to integrate CER, in our case that of Artificial intelligence, to challenges and opportunities in the Global South, at the ground. Thus, our orientation is not that of Computing curriculum, whether international or national, but the bottom-up demand for AI in the context. Curriculum needs to serve, rather than dominate — also CER.

Within the Global South, Africanizing any curriculum is a widely recognized goal, going hand in hand with Afrocentrism. However, Africanizing also raises concerns, especially within engineering and science, like Computing. Easily, Africanizing has been identified with efforts to reduce the level, technical content or learning goals at the cost of contextual relevance, compromised demands or attraction of the curriculum to high school students. One of our students got his inspiration towards AI from Elon Musk, born African. The student's goal to make Africa a future superpower apparently coincides with much of his peer students. Recent movies with black heroes developing or using AI, exemplified by Black Panther or Outside the Wire, have popularized and concretized the vision. In fact, Africanizing a curriculum should be understood as a way to raise the level of learning, getting beyond the state-of-the-art of even fast the curricula of fast changing subjects such as Computing.

A key principle in Africanizing our course was to keep it open in many dimensions relevant to Africa. In our case, we opened the curriculum by

- *hybrid access*, giving the course as a hybrid one that allowed flexible participation either online or attending the course physically;
- *guest lecturers*, challenging the participants to step out of the comfort zone of a pre-given content towards issues of contemporary interest;
- *public presentations*, given by the students beyond the boundaries of the university to the general public, to receive tricky questions from an audience not professionally exposed to AI;
- *partnerships*, to extend and deepen the relevance of the course;
- *enhanced entrances and exits of the course*, in our case two entries and two exists; and
- *international participation*, by inviting students from overseas.

The urgent demand for AI coders raises the question of the focus between soft skills and hard skills in an AI course. Since the emphasis of our course was to unlock students' interest in AI, we chose to prioritize concrete applications of AI, even when that led to compromising the technical contents. This was based on discussions with several students that complained about the conventional focus on theoretical, and thus technical, excellence. Our argumentation for the practical orientation of the course was that students need to, first, become aware of the potential of AI in a set of real-life applications field, to, later – even after the course, develop hunger for learning the technical skills needed to respond to the real-life challenges. However, the fact that most students seemed to be uncertain of their programming skills, indicates that a creative tensions of soft and hard skills need to be realized as programming workshops throughout the course, to ensure that students can integrate AI components to their artifacts throughout the course.

As of the intellectual property rights, the Namibian university retains 60% of the rights of students' innovations. This might be true for many other universities that are struggling at the time when governments are reducing their financial support for universities: universities need to find other ways for increasing their income. However, the current policy might not be ideal as an incentive for students to excel their invention capacity. In contrast, a more generous policy would probably inspire students to put more time and effort to create solutions that they would profit of, even if they would share part of it with their university.

A. Limitations

The course was iterative in planning and changed over the course of time. This complicated analyzing the course.

B. Recommendations for practitioners

1) Implications for Computing Curriculum:

- *Contextualizing* the curriculum to critical challenges and opportunities of the environment motivates students to come up with creative ideas, applied to their very context. In our case, the applications areas of AI were learning and farming. Both of these are critical for Namibia, as challenges as well as opportunities. First, Namibia, as an African country with young demography, with a vast opportunity that distinguishes the country from the Global North coping with ageing population, has the challenge to train her youth to relevant jobs. Second,
- *Getting confidence* needs to be a key goal in a computer scientist's education. The observations among the students showed that their achieving concrete results gave them confidence and further encouraged them to learn the contents of the course. However, in our case the concrete results as robotic gadgets came at a relatively late stage of the course.
- Rather than taught as an independent course, *Ethics of computing* need to be integrated within other courses. In our case, the lecture of Ethics in AI showed that students did not even have an idea of what the topic of the lecture meant. However, when explained, the lecture promoted a rich and deep discussion on the topic.

2) Achieving 4Cs in higher education:

- Creativity gets inspiration from working in an actual problem and being invited to expose the solution to outsiders.
- Critical thinking requires experiences in which students see the limitations of their own work in progress, requiring them to identify the problems and solve them.
- Collaboration skills develop in a team assignment that extends throughout the course. Our findings show that identified problems, such as unfair division of working load, can be discussed within an open lecture.
- Communication competences grow in situations where students need to explain their evolving solutions within their own team, with the rest of the course participants, and with outside audiences.

3) Integrating higher education to sustainable development: Environment, economy, socio-cultural context and ethics are the key aspects that need to be addressed when developing any education that can transform people's lives in the long run, in a sustainable way. Our results of applying AI for societal problems indicate that this is possible and even motivating.

C. Further research

A detailed analysis of student feedback is critical for deeper analysis. In particular, we will be interested in the students' prior expectations of AI, how they changed over the course, and how students think that they can make use of the course in their future profession. A key focus would be to identify the ways that an AI course can empower students to find their own interests in AI, especially as entrepreneurs working with real-life customers. We will also look into how practical problems will open their mindsets to get deeper into technical excellence, certainly demanded of AI-oriented computer scientists.

Methodwise, further investigation of Africanized AI education would require a creative combination of action research for renewing AI curriculum, design science research for developing novel pedagogic and digital artifacts for AI education, and grounded theory to make sense to the interrelations within the emerging but still novel area.

VII. Conclusions

We carried out the undergraduate course in Artificial Intelligence in a novel way that emphasized the creative application of artificial intelligence to meet the contextual requirements, especially those of the Fourth Industrial Revolution (4IR). However, unlike the usual, top-down, strategic approach adopted in several white papers and governmental recommendations, we chose the approach that helps Computer science graduates to explore and get inspired by the opportunities of AI at the ground.

Our findings can be summarized as follows:

- Africanizing an AI course can spark the interest to invent AI-based solutions to key African challenges.
- An AI course needs to facilitate interaction between developing a working, robotics-based prototype and learning to integrate the coding-intense components into it.

- Teamwork within the AI course requires continuous and transparent elaboration of every team member's contribution to the project.

The results indicate that Africanization gives a novel impetus to reform Computing education. This applies, first, in Africa, but secondly and equally importantly, beyond Africa.

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