

## **Impact of the Robotics inspired Science Education (RiSE) Program on Education in Ghana**

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### **Abstract**

With the current drift of the global economy from an industrial age to a knowledge-based and conceptual/creativity age, the focus on science, technology, engineering, and mathematics (STEM) education and critical thinking has been a major focus of most countries. In Ghana, one principal issue raised by industry is that many university graduates lack skills which complement their technical knowledge such as problem solving skills and team work. In an attempt to address this problem and to prepare students with adequate skills for the 4th industrial revolution, many countries and institutions have resorted to varying methodologies of implementing STEM based learning either as part of regular education or outside school hours. In 2011, the Ghana Robotics Academy foundation (GRAF) introduced the use of robots in inspiring Ghanaian students to aspire for higher education in STEM related subjects and to help develop problem solving/critical thinking skills through its RiSE program. This paper details the activities and impact of GRAF's

RiSE program in addressing the industrial challenge mentioned earlier. In this paper, a narrative of RiSE activities is discussed and the 2018 RiSE survey is used to assess the impact of the program. It was established that the incorporation of robotics related experiments in students' learning activities creates problem-solving skills in them, that robotics can be leverage to simplify complex engineering problems and also that robotics inspires students to pursue higher education in STEM related courses including those which employs and deploys high end technology.

**Keywords:** Robotics, STEM, Education, Global Economy, Lego EV3

### **Introduction**

According to the 2017 World Economic Forum, Education and work in Sub-Saharan Africa will determine the livelihoods of nearly a billion people in the region. The share of the region's population with at least a secondary education is set to increase from 36% in 2010 to 52% in 2030 translating to about 15 to 20 million increasingly "well-educated" young people joining the African workforce every year for the next three decades (World Economic Forum, 2017) (WEF, 2017). If properly trained, this workforce would make Africa a key player in global human capital provider. On the contrary, if the educational system fails to equip this population with the relevant skill set, the region is likely to face the worst unemployment problem of all time.

There is however, little definition of tried and tested ways of grooming students for optimal performance in our quest to equip students with practical STEM and thinking skills. This is evident in the poor performance of students globally recorded in STEM related subjects (OECD PISA, 2015). The Organization for Economic Co-operation and Development's (OECD) results of the 2015 global ranking of 72 countries based on assessment of 540,000 students who took part in the Program for International Student Assessment (PISA) revealed that only 29 (40.03%) countries ranked above the OECD average in Mathematics with strongholds like America falling 11 places

below the average and only 28 (38.9%) countries ranked above the OECD average in Science (OECD PISA, 2015).

In Ghana, the 2016 results released by the West African Examinations Council (WAEC) showed that less than half of a total of 247,262 Ghanaian students who sat for the West African Senior Secondary Certificate Examination (WASSCE) obtained the minimum grades to gain admission into universities (Jinapor, 2016). According to the report only 32.83% of the students passed in Core Mathematics and, only 48.48% secured passes in Integrated Science (Jinapor, 2016). In spite of this degenerating report, Dr. Ahmed Jinapor, a lecturer at the University of Education, Winneba, revealed that the outcome of the 2016 WASSCE was an improvement on previous years' though he was quick to add that the marginally better performance of students was still not the best.

The situation is alarming with existing statistics predicting that about 80% of jobs to be created in the next decade will require STEM skills (XPrice, 2011). The 2015 World Economic Forum report indicate that 41% of all firms in Tanzania, 30% in Kenya, 9% in South Africa and 6% in Nigeria are already complaining of the inadequacy of skilled workforce adding that this is as a result of most of the available jobs requiring the use of some form of digital technology.

### **The Robotics Inspired Science Education Program In Ghana**

To improve the efficiency and throughput of the education system in this era, it remains critical to explore efficient techniques and tools to augment the current delivery mode in schools targeting at improving STEM, creativity and critical thinking skill development. In 2011, the Ghana Robotics Academy Foundation (GRAF); founded by Dr. Ashitey Trebi-Ollennu, introduced Ghanaian Senior High School students to Robotics and Programming through the Robotics inspired Science Education (RiSE) Program with the objective of creating and nurturing a sustained interest in hands-on science and fostering a strong interest in Science, Technology, Engineering, and Math (STEM) subjects among high school students (GRAF, 2014). An article

published by the IEEE Control Systems magazine revealed that 95% of 200 RiSE participants reported the program had provided them with challenging real-life experiences that complement their academic curriculum by connecting theory to practice (Trobi-Ollennu, 2014).

The RiSE program remains committed to demystifying science through futuristic educational transformation and helping every student to succeed. Our (GRAF's) proven and unique system for learning has never been more relevant: a hands-on, minds-on approach– the core of which is the enduringly engaging and versatile LEGO brick and Lego Mindstorm Programming Environment – designed to help students take ownership of the learning process, enabling them to actively develop the problem-solving skills and collaborative outlook necessary to become creators, not just consumers of knowledge. The program has made bare the power of its hands-on technology and curriculum in engaging and motivating students to learn science, technology, engineering, and math concepts while equipping them with the real-world knowledge and 21st century skills required to be successful and competitive in today's global society. Up until 2017, RiSE activities had seen Ghana participate in a number of international competitions in countries including: US, Malaysia, Indonesia, Russia, India, Costa Rica and also the recipient of prestigious awards including the under listed:

- 2017: A RiSE team finished in the top 12 (from over 160 competitors) in the 2017 GOOGLE'S MOONBOT CHALLENGE
- 2016: Admission of students from the RiSE program into top class universities in the USA. The most outstanding being full scholarship admission into UC Berkley. Selected from over 83,000 applications from around the world.
- 2016: A RiSE team teams finished as Semi-finalists in the World Robots Olympiad (India) in Open Category for Senior High.
- 2016: A RiSE team received the TOYOTA INNOVATION AWARD at the ROBOFEST

WORLD CHAMPIONSHIP in Michigan (US) by one of Ghana teams

### **2018 RiSE Activities**

In 2018, the program introduced 576 to a more tacit – ‘knowledge in action’ method of learning to augment the traditional declarative and propositional knowledge in 32 schools across the country. The first set of skills passed on to students was an introduction to calibration of measuring equipment and sensors using linear equations. Students were then thought basic programming constructs and how to convert ideas into pseudo codes. Lego EV3 robots were used to introduce students to how programming, mathematics and physics can be merged into cyber-physical systems of relevance to daily human activities. Students were thought to be able to apply classical control ideas and techniques ranging from Proportional Controllers, Proportional-Derivative (PD) controllers and Proportional-Integral-Derivative (PID) Controllers to program line following rover robots. Students were also introduced to gears and their use in automation. In-depth programming principles including code re-usability, functions, multiprogramming, program modularization and program debugging techniques were also thought as part of the RiSE program in 2018. Late September 2018, 41 teams (6 students in each team) from 25 schools registered and took part in the annual RiSE competitions held in four zones across the country. There were a total of about 560 students present out of which 246 took part in the competitions. In 2011 and 2012, all participants used big-band control with un-calibrated light sensors during the RiSE competitions (Trebi-Ollennu, 2014). Participants of RiSE competitions in 2013 and 2014 demonstrated great improvement with 75% of teams using proportional controls and 25% of teams using PD controls for Autonomous navigation. At the RiSE 2018 competitions, 68% of team members had adopted code re-use and optimization techniques with self-built blocks that allowed reconfiguration by argument passing. 95% of teams used a mix of Proportional Control and PD controls for autonomous navigation. 75% of teams had segmented their programs using sensor triggered loop

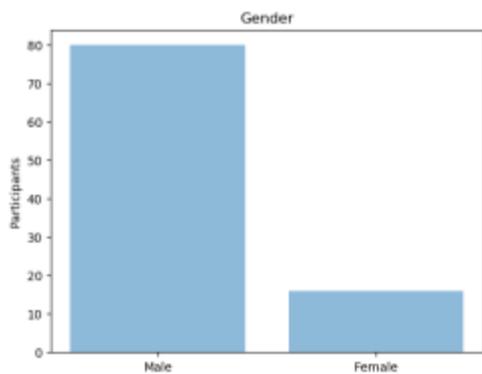
interrupts for transitions between sequenced programs. All team members used calibrated sensors and 30% of team members succeeded in the use of sensors for objects detection and gear mechanisms for grabbing and lifting of these objects in the path of their robots during the Autonomous Rescue Challenge.

In 2018, twenty students from the RiSE program were engaged international activities. The activities and the performance of these students in the respective activities are as detailed below:

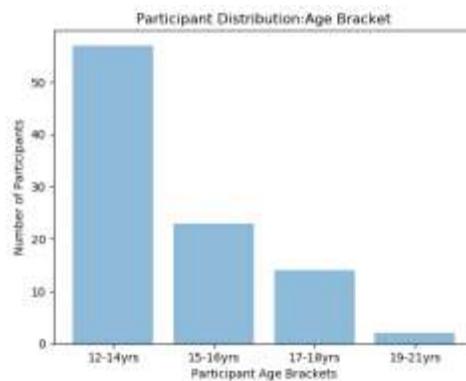
- ROBOFEST 2018, USA: A RiSE team finished 8th overall out of 23 teams in the Seniors Game category; the first time in 13-year history an African team broke into the top 10.
- 2018 UNESCO CULTURAL EXCHANGE PROGRAM (USA): A RiSE delegation made of one (1) GRAF staff and three (3) students from high school delivered training in the special feature of robotics.
- 2018 SHELL OCEAN X-PRIZE CHALLENGE: A RiSE team (of two students from junior high school and one student from senior high school) in the SHELL OCEAN X-PRIZE global competition placed 2nd and 3rd in two separate categories of adjudication (from over 1,500 competitors)

### **2018 RiSE Survey**

A survey was conducted on randomly sample 150 competitors during the national competitions to gather data for evaluating the impact and effectiveness of the 2018 RiSE program. Below is a detailed discussion of the survey output.

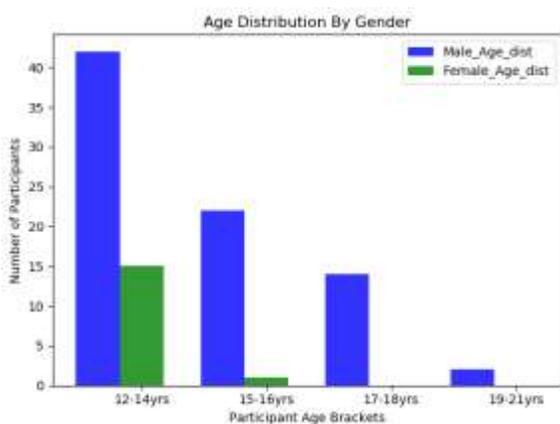


**Fig. 1:** Participants Gender Distribution

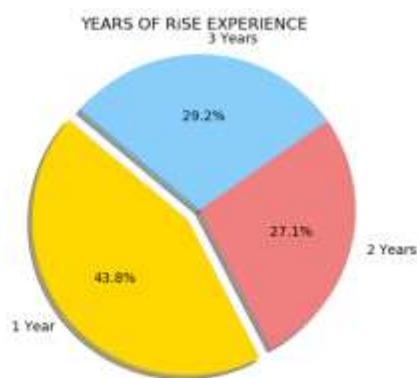


**Fig. 2:** Participants Age Distribution

The survey had 64% response rate of which 83% were male students and 17% were female students as shown in *Fig. 1*. The age distribution of participants is as shown in *Fig. 2 and Fig. 3*. 59% of the students forming the majority of participants were between ages 12 – 14years. 24% of participants were between ages 15 – 16years and 15% of participants were between ages 17-18years. There were just 2% of participants between ages 19-21years.



**Fig. 3:** Age groups by Gender Distribution

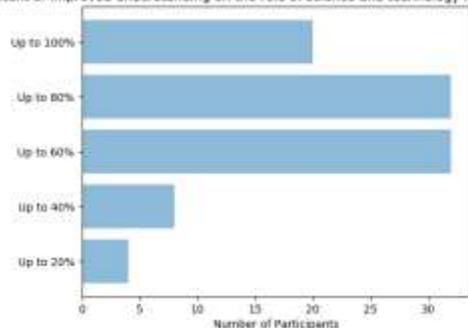


**Fig. 4:** Years of RiSE Experience

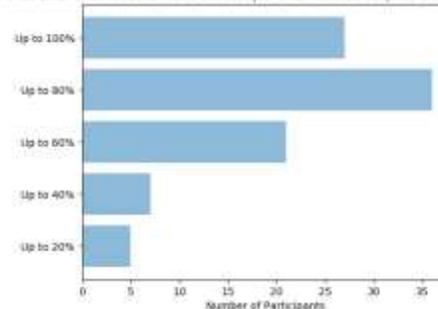
The response of the survey as visualized in *Fig. 4*, shows that 29.2% of the students had been in the RiSE program for 3years and above, 27.1% had been in the program for up over a year up to two years and 43.8% of students forming the majority had been in the program for less than a year.

All students reported varying levels of benefits of the RiSE program as detailed the following visualization of students responds to specific questions:

extent of improved understanding on the role of science and technology in everyday life



to what extent has robotics made the study of STEM related subjects more fun and easier

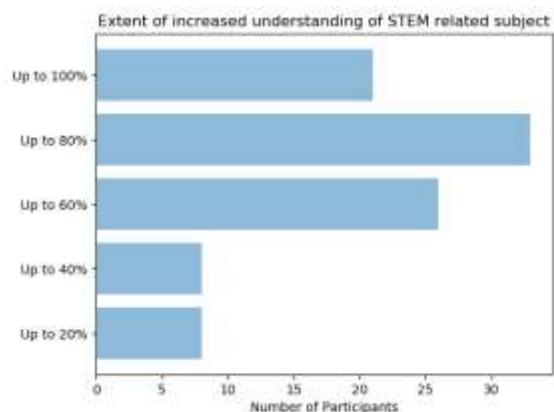


**Fig. 5:** RiSE impact on STEM practicality

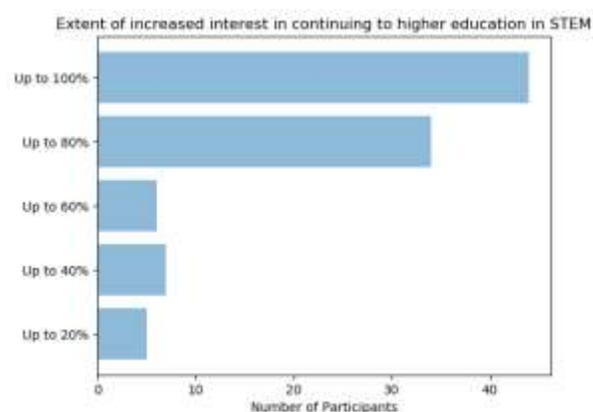
**Fig. 6:** RiSE impact on STEM studies

Fig. 5 and Fig. 6 show the respondents reported of RiSE impact on their understanding of the role of STEM in everyday life and an the extent to which the program has made the study of STEM related subjects easy and fun. 67% of students reported between 50 – 80% improvement in their understanding of the role of science and technology in everyday life. 21% of students reported between 80 – 100% improvement in same and 12% reported up to 40% improvement in their understanding of the role of science and technology in everyday life through the RiSE program.

In responding to the degree to which robotics had made the study of STEM related subjects fun and easy, 66% of the students reported between 60 – 100% improvement, 29% of students reported between 30 – 60% improvement and the remaining 5% of students reported up to 20% improvement.

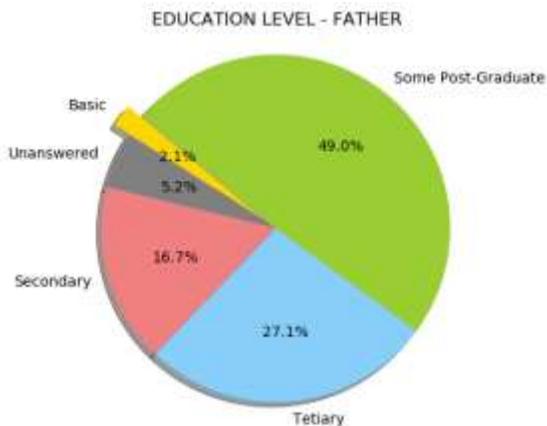


**Fig. 7:** RiSE impact on STEM understanding

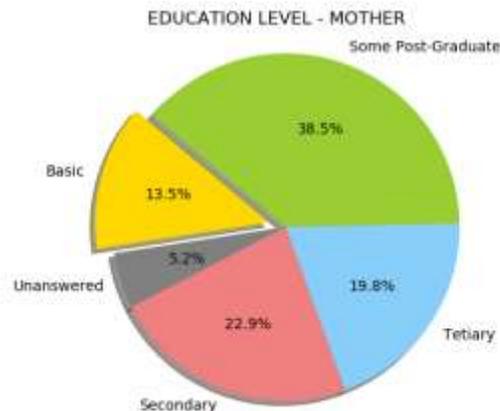


**Fig. 8:** RiSE impact on STEM interest

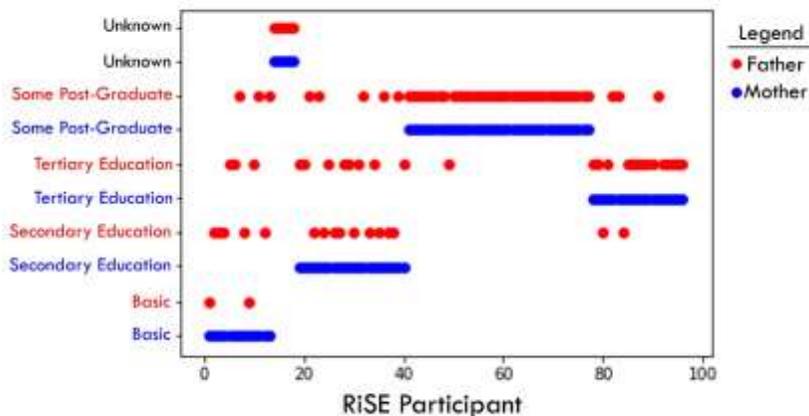
In *Fig. 7*, 80% of the students responded to over 40% improvement in their understanding of STEM related subjects in their regular classrooms. The remaining 20% of students reported up to 40% improvement. With the objective of the RiSE program being to inspire students for higher education especially in fields related to STEM, the response of the survey ascertained the program is achieving its core objective. As seen in *Fig. 8*, Over 81% of students responded showed between 60 – 100% interests in continuing to higher education in science, technology, engineering or mathematics (STEM) with a majority of them having interests between 80-100%. The remaining 19% of students showed varying interests up to 60% chances of continuing to higher education in STEM related fields.



*Fig.9: Father's Education Level*



*Fig. 10: Mother's Education Level*



*Figure 11: Parent's education level per participant*

*Fig.9-11* matches students to parent's education level. In details, 39% of the students in the RiSE program came from homes where either or both parent had some form of post-graduate level of education. 22% of students came from homes where either or both parents had some form of second cycle education. 20% of students came from homes where either or both parents had some form of tertiary education. 14% of the students came from homes where either or both parents had some form of basic education and the remaining 5% of students refused to reveal their parents educational background.

## Conclusion

In this paper, a tacit approach to training students for critical thinking and practical skills acquisition using robots is deployed in engaging students between 12-21 years. PID control principles are combined with procedural and object oriented programming concepts in a hands-on training curriculum that allowed students to program robots for autonomous tasks. A survey is conducted and responds are analyzed to establish that this training approach has a positive impact on students' understanding and in inspiring students to choose STEM related subjects/courses for higher education. It was established that the incorporation of robotics related experiments in students' learning activities creates problem-solving skills in them. Secondly, it was established that robotics can be leverage to simplify complex engineering problems (such as in Proportional Controllers, Proportional-Derivative (PD) controllers and Proportional-Integral-Derivative (PID) Controllers) and thereby find solutions to such more easily. Thirdly, that robotics inspires students to pursue higher education in STEM related courses including those which employs and deploys high end technology. Finally, it was established that the higher the education level of the parent(s) the more likely it is for them to influence their ward to pursue STEM related courses/careers.

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