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Strategies for Gender Sensitive STEM Curriculum for Sustainable Development

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Abstract

This paper is based on the premise that girls are not as many in STEM disciplines and careers as needed, as established by various statistics and researches, as well as anecdotal evidences. It discusses, the nature of the STEM curriculum that will effectively engage girls in STEM-related careers. The process of developing such a curriculum and its learning outcomes are also considered. The paper advocates for the "voices of girls"and those of their parents, among others, as a first step to such curriculum development, which also must be continuous. In addition, the paper advances a STEM curriculum that ensures that girls who do not choose STEM subjects eventually and STEM careers later on in life develop scientific attitudes and science process skills which ultimately result in more women contributing to national development.

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Introduction

There is abundant empirical data and evidence with substantiated anecdotal evidence that girls are fewer than boys in STEM (Aremu 2006; Ekine 2014). While I would not try to put such evidence forward in this paper (though this may sound unscientific), it must be understood that this is the premise for the discussion about strategies for a gender sensitive STEM curriculum. My task is to provide strategies that should engage more girls in STEM and which could be integrated into a curriculum for STEM.

This paper works with a wide-ranging definition of female engagement in STEM. Whereas the general consensus is about girls in science and technology related careers, like computer science, space science, sobotics, engineering and at times the medical sciences, the view of this paper is more inclusive. It must be understood, that having said all and done whatever is necessary, not all girls would go into STEM-based careers. A sustainable female engagement in STEM, can be achieved through having all females acquire scientific attitudes (curiosity, skepticism and humility) and science process skills (observation, communication, classification, measurement, inference, prediction) at all levels of education, but predominantly at the foundation level. If this is achieved, whatever career these girls choose in life and whatever problems they may encounter in life, they would possess the capabilities that would enable them to be effective in those careers as well as be able to solve problems.

Therefore, the focus of this paper is on curriculum strategies that would enable the girl child acquire scientific knowledge, develop science process skills and a scientific attitude such that firstly, they may become scientists or go into science-based careers, and secondly, if they do not go into science-related careers would go into their careers with scientific attitudes and science skills

Stem Curriculum for All Girls-Why?

Why should we have strategies for engaging girls, especially in STEM? The reasons we present would go a long way in determining the process and the end- product of our curriculum.

Trying to answer the why question has produced some of the following answers as presented in Box 1.

The summary of all these is captured in this phrase “What a man can do, a woman was either not made to do or was made to do differently” (Aremu, 2001).

The essence of this phrase is the uniqueness of the female gender, which should not be eroded in this highly competitive world of “wanting to be”. There are things only women can do effectively and efficiently; same with the male gender. The thought that girls are unique should be the starting point of any kind of gender sensitive curriculum. Some may disagree with the phrase on the premise that women can do what people feel is in the purview of men alone. However, the phrase is not about “the things men do”, as many may want to imply. The phrase is not meant to give a soft landing and an excuse for women not to engage in “tough” things. The phrase does not insinuate that girls cannot do what men are doing. They can and in many cases they do. The phrase, however, shows that women can do such things differently and achieve a great result and they don't have to do those things to show men that they are capable. There is always a unique female angle to doing things that can be done, whether they are things stereotyped as being for men or not. This makes life complete and fulfilling. As women, we owe that to our creator (for me, that is God).

This line of thought is not actually unique to me alone;others have spoken about it in different ways. For example, according to a reporter, Okonji Emma, in his article in the online version of This Day newspaper of May 2018, the United States Consul General in Nigeria, Mr. John Bray is quoted as saying that “the blunt truth is that without women's inclusive participation, any gains in economic growth and development, as well as advances in science and technology, will be lopsided and unsustainable. Therefore, it is critical that women's voices at all levels, find representation in collaborative solutions that will have the impact on them”.

He went on to say that if barriers to the participation of women in STEM are eliminated, the result would be better families, better countries and a better world. What better positive motivation apart from competition, therefore, do we have to ensure more female engagement in STEM? The uniqueness of womanhood, coupled with societal and cultural stereotypes and societal

expectations, implies that deep and serious thought must be taken in planning curriculum activities for girls, especially when it relates to STEM.

STEM Curriculum - What?

A working definition of a curriculum adopted for this paper is that of Oluoch (1982), who defines curriculum as 'all that is planned to enable the students acquire and develop the desired knowledge, skills and attitudes'. These are the skills and attitudes, desired by the society. Therefore, a STEM curriculum in this context comprises " all that is planned to enable students acquire and develop the desired scientific knowledge, science skills and scientific attitudes". The emphasis here is planning, which implies something that has been thought through and designed. "Students" as contained in this definition would be "girls". The learning outcomes of this curriculum would be scientific knowledge, science skills and scientific attitudes. These learning outcomes are such as are desired by the society. The expectations of the stakeholders society, is to have more girls in STEM. So, the scientific knowledge, science skills and scientific attitudes expected to be developed by girls through a STEM curriculum would be such that would lead to more female engagement in STEM. There is, therefore, a need to understand what the scientific knowledge, science skills and scientific attitudes that would be the outcome of the curriculum are. This is because the learning outcomes would be the tool for more engagement of girls in STEM.

Scientific Knowledge

Scientific Knowledge is what most people refer to when they discuss Science. It is actually the content of Science, the basic concepts. It is acquired through academic as well as hands-on activities. These contents include concepts such as soil, air, plants and animals, the solar system, the human body, work energy and forces. At the basic education and senior secondary school levels, these concepts constitute most of the contents of the following subjects: mathematics, biology, chemistry, physics, agricultural science. Without an understanding of these concepts, it is impossible to appreciate Science, its worth and its beauty and, in addition, to actually do Science.Since Science is about the world around us, it should not be difficult to understand and relate

with. However, it seems that the moment it became a subject to be learnt the seriousness of learning set in with its responsibilities and anxieties.

One of the key considerations for girls in science would be relevance. Females generally want to see the relevance to life, love and living of the things they are learning. Since science is about day-to-day living, it should not be difficult to link science to girls. If such provisions are not made in the curriculum, it becomes the imperative of the teachers to ensure such connections.

Scientific Attitude

A person that has a scientific attitude is one that possesses, for example, the following dispositions: open-mindedness, honesty and skepticism as well as curiosity, and humility. This is quite different from attitude towards Science, which encompasses interest, attitude towards scientists, etc. Scientific attitudes can be developed. It is a learning outcome that is most desirable in the 21st century. The list of scientific attitudes to develop could be very long such as contained in this list: empiricism, determinism, a belief that problems have solutions, parsimony, scientific manipulation, skepticism, precision, respect for paradigms, a respect for the power of theoretical structure, willingness to change opinion, loyalty to reality, aversion to superstition and an automatic preference for scientific explanation, a thirst for knowledge, an intellectual drive, suspended judgment, awareness of assumptions, ability to separate fundamental concepts from the irrelevant or unimportant, respect for quantification and appreciation of mathematics as a language of science, an appreciation of probability and statistics, an understanding that all knowledge has tolerance limits and empathy for the human condition. (Author unknown, 1990).

A more recent author (Pudlao, 2012) lists the following as scientific attitudes: belief, curiosity, objectivity, critical mindedness, open-mindedness, inventiveness, risk taking, intellectual honesty, humility, and responsibility. However, the basic dispositions are that of curiosity, skepticism and humility. This is because curiosity triggers new ideas, skepticism encourages attention to the facts and humility helps us discard predictions that can not be verified by research (Jim Carroll University, 2018).

They very essence of these characteristics seems to be averse to some major characteristics of females. Females are usually emotional rather than logical, superstitious rather than reasonable, spiritually focused (religious?) rather than focused on reality. Thus, scientific attitudes could be a major contradiction to a natural tendency and that is why it is very important to put them into consideration in designing a curriculum that targets girls. Female attributes may be an hindrance to deep engagement with science and the process of science. How then do you help females to develop these scientific attitudes without necessarily 'de-femining'(making them less feminine) them? For example, how do we help females to see that although spiritual things, govern the natural, they are not in opposition to it ? In addition, although that, science could be a tool to confirm the supernatural, there is the need to keep searching and researching, with open mind, for things that cannot be explained yet by science because of its finiteness. It must be realized that females experience a lot of things which are in the "unexplainable domain". One of them is the feeling of love. The fact that it is not scientifically verifiable, does not mean it does not exist. As scientists however, we should be willing to change opinion, if and when evidence turns up against our "feeling" or "beliefs".

In themselves, these characteristics of a scientific attitude could be developed through various science contents to promote an appreciation of Science. However, if students do not end up as science students, they would still have benefitted greatly from science.

Scientific Process Skills

The science process skills namely, observation, communication, classification, measurement, inference and prediction are processes of doing science. They are skills that scientists use in the process of scientific investigations. According to the manual on Science Process Skills by the Clean Virginia Waterways project of the Longwood University (N.D), when students are taught to use these skills in Science, they are indirectly being taught skills that they will use in the future in other areas of their lives. As a specific learning outcome of Science. it is necessary that the Science curriculum should reflect these skills in such a way as to take care of the interest of both genders. These skills can be taught in such a way as to attract girls to Science, if areas of interest of girls are put into consideration, for example, things that have to do with fashion, home

making, cooking, use of money and also becoming someone of value through innovative contributions to the development and growth of the society. These would call for more women being part of the curriculum development process, because there is no one that can think like and for women than women. In teaching processes also, it is pertinent that teachers be skilled in adapting curriculum content to the interest of girls.

Curriculum Development in STEM –The Process

The process of developing a gender sensitive STEM curriculum is the same process for any type of curriculum, whether it is for formal or informal learning processes. The process includes the following: gathering information, design, building the content and evaluation. For a subject like Science, this process of curriculum development should be undertaken on a regular basis. This is because even though its theoretical underpinnings do not change, the areas of applications keep on changing. Others have also emphasised this.

"There is the need to continually change education curriculum and infrastructure to meet contemporary realities, given the switch from old skills to digital technology, robotics and artificial intelligence". (Dr Oluranti Adebule, Lagos State Deputy Governor, in her keynote address titled: "Building an inclusive 21st century workforce: The girl-child challenge" at the 2017 Science and Technology Fair organised by Dr Christopher Kolade Foundation (CKF) through its STEMMA Hands-on Empowerment (SHE) Initiative).

The process of gathering information (which also must be done continually)may be the most important one in the processes of developing a curriculum. If information and data are systematically gathered, then there will not be a mismatch in purpose and content and delivery in the curriculum. When applied to the STEM curriculum, we should be asking the following questions.

- Who is my target? This is not just about the gender, it is also about the characteristics of the gender, the likes, the tendencies, potentials and weaknesses and the preferred career choices, hopes and dreams.
- What attitudes do they have towards the subject? This is very vital. Do they think it is only for men, boring and difficult? Do they think it is irrelevant to their future? What factors have influenced these attitudes? What does research say about these attitudes?

- What does the learner already know? Have they encountered Science in their day to day life? How? Where?

It is after these have been clearly answered that the next stages would be engaged in. At the design stage, you identify your goals, learning outcomes, content, instructional strategies, resources and methods of assessment. In addition, you plan how all these would be sequenced and evaluated. After this, you can build the content, putting all you have identified together and then finally, evaluating.

Curriculum design could be of three types (Schweitzer, 2017), It could be subject-centred, learner-centred or problem-centred. STEM curriculum could benefit from the three designs depending on the levels of education and whether it is for formal or informal learning. A learner-centred designed may be preferred for the lower levels, that is basic education, whereas the subject-centred and the learner-centred designs would be preferable for the senior secondary level, with an introduction to the problem-centred design. However at the higher education of level, the design should be basically problem centred.

This paper presents some information that has been garnered which could influence the attitudes of females in Science and which should determine the strategies that could be used. Apart from research, stakeholders' opinions are vital in curriculum design. Members of the community (international and local, schools, teachers, students, graduates, captains of industry, parents, resource managers, counselors, opinion makers, etc) should be consulted. Two groups whose opinions are not usually deliberately sought for, so as to find out what influenced their choice of STEM, while developing curriculum are girls (who chose STEM as subjects and as careers, as well as those who did not) and their parents. These are girls who may just be out of college having completed science and technology-based careers. There is a need to engage these groups in reflective thinking about their earlier years to consider factors that could have influenced them. The parents, under whose supervision they grew up also need to be engaged. It becomes more interesting when these two categories of students may be found in one family. What predisposes a girl to choose science subjects and her sister not to choose the same subjects even with both of them

exposed to the same learning experiences and home environment? This calls for investigations.

Voices of Girls

When asked the question, what do you think influenced your choice of Science subjects, here are some comments gathered:

"I didn't see myself as a social science student"

"From my early days, I wanted to be a medical doctor, so I didn't think about any other subjects except science" (One ended up as a computer scientist, the other psychologist and Public Health practitioner)

"I never really enjoyed non-science subjects at the junior classes"

"Most of the arms of the senior secondary classes were Science classes, we had four arms of science classes, one arm of arts class and one arm of social science class. It seems Science was the expectation and in vogue".

"I found subjects like history, B.K. and literature too tasking; mathematics was easier".

"I didn't like the girls in my class and more girls went to the Arts class, I preferred talking about sports and novels with boys, instead of fashion".

"Because I enjoyed Maths and Integrated Science from primary and junior secondary school, I wasn't a big fan of Social Studies".

"I think Sciences challenged me to think outside the box more than Arts. Although these days, it seems like it is more regimented and it is Arts that actually challenges us in terms of creativity".

"I wanted to be like my Mum and dad" (Both parents had an engineering background).

"I chose to take science courses because it was like the norm in my school. I also was not sure of what I wanted to be in at that time, also it seemed that smart people did science. I eventually chose a social science career because I was more excited about economics and geography. If I had proper counsel, I would have opted for the social science subjects and class. I still passed all the sciences" (She read Human Resource Management in the University).

The latter also spoke about her friend who despite being the best in every subject including the sciences, opted for the Social Science class and a career in Investment banking and this surprised everyone because the expectation was that she would have chosen the high flying Science careers; she had the intelligence. About her she commented as follows "My friend was the last in her family. She had siblings who were already out of school and working and she benefitted from their wealth of experiences. So, she did not waste time doing what was in vogue in the school then(Sciences). She went straight to where she could fulfill her career requirements "

The following are comments from students who participated in the 2017 Science and Technology Fair, an event organised by Dr Christopher Kolade Foundation (CKF) through its STEMMA Hands-on Empowerment (SHE) Initiative – an immersion programme aimed at offering girls from low-income and middle-income families an opportunity to experience science and technology in a simplified way.

Blessing Samuel, an SS 3 pupil of Omole Senior Grammar School in Ogba area of Lagos, said she would not accept the stereotype that tough science-oriented subjects were meant for only boys. This misconception, she said, had led many girls away from science and technology.

Misturah Isiaq, a 16 year-old pupil of Estate Senior Grammar School in Ilupeju, said low self-esteem is the reason many girls abandon science to embrace other disciplines. But, Eneh Abah, an SS 3 pupil of Babs Fafunwa Millennium Senior Grammar School in Ojodu, who switched from science to an Arts-oriented class, said she did so to pursue her passion. Miss Soaniabari Luckyman of Ijeshatedo Senior Grammar School in Okota said she was studying science because she loved engaging her brain to find solution to difficult situations. Some other examples of experiences growing-up of girls that influenced their choice of Science as a career are presented below:

1. Patty Brubaker, the only female in her high school physics class now runs a water treatment plant

Patty Brubaker grew up working on a cattle ranch outside of Lander, Wyoming, with her two sisters. When some little girls were playing with dolls and experimenting with makeup, Brubaker and her sisters were learning how to haul hay and drive a tractor. She saw her mother and father working hard, side by side at the family's meat packing plant. “I was always kind of a tomboy,” Brubaker said. “I never cared much for girly things, and I've never been afraid of physical labor.” (https://denverwatertap.org/2017/03/02/says-girls-dont-science/)

2. Bethany Downer, Scientist-Astronaut Candidate, Project Possum

Growing up, without realising it, my role models were always women. This included my mom and grandmothers, but also in school when assigned hero or role model essays, I always selected distinguished women.

Role models are of integral value to young women. I'm confident that having a visible example of a profession or career that a young person wants to achieve can be highly motivating and validating for them.

When asked “How did your family help to shape your career path in STEM?” She had this to say

Aside from my family being extremely supportive and my parents coming from engineering and science backgrounds themselves, while in high school I participated in several engineering and science camps. I was actively exposed to many STEM areas that helped me decipher what my specific interests were. I am forever grateful for the support that my family gave me since I discovered my love for space, as they always encouraged my academic and professional pursuits, whatever and wherever they were.

(http://rocket-women.com/2018/09/meet-a-rocket-woman-bethany-downer-scientist-astronaut-candidate-project-possum/)

3. Dr Chiara Mingarelli, Astrophysicist, Flatiron Institute When asked to comment on her journey to astrophysics and to where she is now? She says

I grew up in a small town called Rockland, Ontario, close to Ottawa – the capital of Canada. I loved looking up at the night sky, full of stars, and dreaming of making a discovery. When I found out about black holes, and that one could study black holes for a living, I was hooked!

Who were your role models when you were growing up? How important are role models to young women?

My parents read me Eve Curie's biography of her mother, Marie Curie, to me as a bedtime story. I learned that Marie Curie won 2 Nobel Prizes, so I set out to win 3! This was before I found out that only two women have ever won the prize, despite there being a huge pool of talent to draw from, so I am not particularly hopeful of this anymore. Instead, I hope to be a role model myself, and encourage women to pursue what they are passionate about, especially in STEM fields where we are underrepresented.

(http://rocket-women.com/2018/05/meet-a-rocket-woman-dr-chiara-mingarelli/)

4. Kristen Facciol, Robotics Flight Controller, Canadian Space Agency (CSA)

When asked to comment on her journey to the space industry and to where she is now?

My journey began when I was about 10 years old and was able to attend Space Camp in Montreal, Canada. I learned about the Canadarm, the Space Shuttle program, and the Hubble Space Telescope, and immediately became intrigued. Space exploration was a passion that fuelled my interest in science and math.

(http://rocket-women.com/2018/03/celebrating-international-womens-day-2018-meet-a-rocket-woman-kristen-facciol-robotics-flight-controller-canadian-space-agency-csa/)

The video by Microsoft for its DigiGirlz programme titled "Girls Do Science", is also another eye opener. The videobegins by showing young girls discussing their initial positive feelings about and experiences with technology. "It can really help you uncover like little, small little secrets," says one. Another describes a garage door opener and website she built, and yet another shows off a computer she constructed. Their initial interest is hardly the exception to the rule, the video says, noting that seven out of ten girls are interested in science.

But, these girls reveal, there came a time when their seemingly limitless interest in the field became restrained.

" Then, I started thinking it was more of a boys' thing" "In commercials I saw a lot more men doing it," one says. Another adds, "There used to be a girl in the robotics class but she quit, so I'm the only girl left."

"I just think that inventing is for boys because they have Albert Einstein — he invented, he was a guy — and Benjamin Franklin also," says another.

(Report by Julie Zeilinger - March 17, 2015https://mic.com/articles/112956/powerful-ad-shows-why-more-young-girls-don-t-enter-science-and-technology#.Z5JVlJYcG)

The implications of all these are many, but I choose to focus on the following as likely influencers of choice of career in STEM, which should impact curriculum.

- Natural inclinations and interest- for many girls in STEM, they just liked Science
- Parental Background- parents careers, parents support
- Vision of a future career
- Early exposure to mentors and science programmes – camps and science fun programmes

3.0 Implications for Curriculum Design and Strategies

Table 3.1 presents some of the suggested strategies for STEM education for girls, based on the implications derived from the likely influencers identified in this paper. It should be understood that the four influences identified, are not presented in the order of importance or are they the most important out of all the likely ones. These ones are identified because some of their implications may have hitherto been hidden and emphasis needs to be placed on them.

4.0 Whole-School Learning Programme/Experience

Each suggestion and /or recommendation could be developed into individual programmes which could be implemented in schools by non- governmental agencies and STEM advocates. They could also be combined to be delivered through programmes such as camps. These would still achieve some positive

effects. However, it would be more effective if a whole school programme is developed. This would be school based, but in association with parents, community members, STEM advocates and professional associations. All these programmes would be integrated into the school calendar, science classes as well as extracurricular activities. All these stakeholders can examine science lesson plans/textbooks for each class level to see points of integration of the suggested activities and also to provide resources (human, information, technology and material), that teachers/schools could use to make the programmes effective.

It should be noted that STEM activities that would attract the interest of girls right from the foundation level should be guided by what Aremu (2018) has put together as a model called the FACE©model for effective learning. FACE© is an acronym for F - Fit for purpose for enterprise and for all. A - Authentic, C - Collaborative, E- Engaging. The 4-component model brings various proven learning theories and researches in learning together to explain how a learning activity could be designed to be effective. Fit for purpose means it is set to achieve a general goal as well as specific objectives, which must be reflected in all aspects of the learning activity. F - also stands for Fit for Enterprise. The students must see how the learning activity can promote enterprise and innovation. Knowledge is no more knowledge for knowledge sake or for passing examinations, but for creative work and innovation as well as enterprise development. Fit for all means it puts into consideration all the learning styles and preferences of students. A - stands for authentic. Students must see how the learning fits into their future, how relevant it is for their present and what problems of the past it could be used to solve. In essence, learning must be fitted into the day-to-day, past, present and future lives of students. C-stands for "collaborative". Various theories show that tasks and problems solved together, bringing the capabilities of each team member most likely would be implemented effectively and would be a better solution. It implies that students must be engaged in collaborative problem solving and team work. Finally E means "engaging". This implies, the engagement of the mind and the hands, engagement in terms of critical and creative thinking as well as experimentation and doing. The model explains that it is possible that learning activities be planned based on these guidelines. There is a guarantee of retention and effectiveness in such learning.

5.0 STEM Interventions for Girls - Some Considerations

The recommendations and suggestions that have been made in this paper were made as if no such strategies existed before in one form or the other. This is not to ignore what has been done but to point attention to some gaps that currently exists in the interventions. Some of the interventions are cited in Table 3 (with websites for further information).

In addition, these interventions are presented for stakeholders to be aware of what has been done in STEM for girls, so as to understand what works and what does not and so that stakeholders may know who they could collaborate with in delivering their interventions. This is especially for school-based, whole-experience intervention programmes, which would need a lot of external support.

One of the shortcomings identified with these and other interventions like them is that they have not been based on a thorough investigation and data gathering from all stakeholders. Even if such has been done, there is lack of documentation on them. Another is that these interventions are not implemented right from the foundation level of education-the primary school. If students are well engaged right from this level, there is every likelihood that they will not loose interest as they go on in school. When interventions are implemented at the senior school level, the minds of girls have been set and, most likely, the girls that we harvest from these programmes are those who were interested in STEM or those who are in-between opinions. Furthermore, some of the initiatives are paid programmes which, of course, is limited to the few that can afford them. In addition, the selection of girls for many of these programmes are already biased to those who have excellent results in their academics (especially Science subjects). However, the major issues with the initiatives are the fact that evaluation and monitoring as well as sustainability strategies are not built into the intervention design. In some cases, the grants, which funded the projects, dwindled or were no more forthcoming and that was the end of the project; therefore, the intervention could not be sustained. This issue of monitoring, evaluation and sustainability is most likely the reason why with the various interventions that have been carried out, effective results have not been experienced in the nation.

The shortcomings and weaknesses of STEM based interventions call for such interventions for girls to be carried out in schools through a well-designed and well-implemented curriculum package. This intervention would however be meaningful if it begins at the foundational level of education.

Summary

This paper has presented the need for more girls in STEM, beyond the usual well-articulated reasons of under-representation and equality. The reasons proffered have been based on the uniqueness of womanhood and the need to

make full use of as well as benefit maximally from the uniqueness. Having established this, the paper explained what the learning outcomes of a STEM curriculum for girls should promote. This is not just scientific knowledge but scientific attitudes and science process skills in such a way that engages girls, is considerate of their attributes, creates awareness on STEM and leads them into careers on STEM. Such a curriculum according to this paper, should be reviewed continuously and should start with a process of information gathering from all stakeholders, but most especially, girls already in STEM and those not in STEM as well as their parents.

The paper further presented some of the "Voices of Girls" in relation to their choice of science/non-science subjects at basic and high school levels as well as STEM careers in the college. The curriculum implication of some identified influencers of STEM engagement for girls was offered. In addition, recommended strategies were proffered. The FACE©Model for Effective Learning was suggested as a guide for STEM activities to be developed based on the strategies advocated. To end the discourse, some examples of STEM intervention for Girls, where cited and what could be their shortcomings which should be planned for in any curriculum that should be developed.

FACE©Model for Effective Learning (Aremu, 2018)

Conclusion

To conclude, what this paper recommends is a curriculum for a whole school experience to engage girls in STEM, which must be implemented right from the foundation of learning.

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