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# The Potential of Socio-biologically Relevant Mobile Applications to Attract Girls to STEM

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# The Potential of Socio-biologically Relevant Mobile Applications to Attract Girls to STEM

**Cover Page Footnote**
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## Introduction

STEM is more than an acronym for science, technology, engineering and mathematics. It portrays a repackaging of discrete subjects – science, mathematics, technology and engineering into an integrated curriculum. It emphasizes a need for blurring of boundaries among specific disciplines which more accurately reflect real-world and designed-world issues, encouraging students to apply knowledge from several fields.

In the 21st century, the power of scientific and technological innovation has become increasingly clear to countries around the world and to lead in this race, they need a suitably qualified STEM workforce. Evidence of this is seen in the United States, where STEM-related jobs have increased three times faster than other fields in the first decade of the 21st century (US Department of Commerce, 2012). In addition, future job data trends from the US Department of Labor (2017) show that STEM-related jobs will continue to increase over the period, 2014-2024.

The representation of women holding jobs in STEM fields is significantly low. According to Nilsson (2015), only 14% of engineers in the current U.S. workforce nationwide are women. This is seen to be a result of an under-representation of women in most STEM-related disciplines in higher education, including engineering. A similar trend is found in Europe where an OECD (Organization for Economic Cooperation and Development) report on gender differences based on data from 35 European countries shows that less than one in three engineering graduates are girls, and less than one in five computer science graduates are girls (http://www.oecd.org/gender/data/whereareto morrowsfemalescientists.htm). Stoet and Geary (2018) note that the under-representation of women in STEM fields is a worldwide phenomenon with evidence for this trend seen in many countries. For example, in Canada in 2016, only 28% of the labor force in science-related occupations were women.

## The Gender Gap in STEM

In the United States, the metaphor 'leak' stem pipeline refers to the alarming rate of attrition of girls from STEM areas of study beginning in the middle school years. Research shows that in the US more that 50% of the girls have lost interest in science by the 8th grade (around 13 years). In the 2015 PISA (Program for International Student Assessment), an international comparison of student performance, U.S. students' scores show a statistically significant difference between 15-year old boys and girls, in *both* science and mathematics (https://nces.ed.gov/surveys/pisa/pisa2015/pisa2015highlights_3c.asp).

The *Microsoft Global Diversity and Inclusion Report* (2016) shares the findings of a similar trend in Europe in a study conducted across 12 European countries including Finland, France, Germany, Italy, Netherlands, Russia and the United Kingdom, with a sample size of 11,500 girls. Researchers found that in the younger years, between the ages of 11-12, girls do show an interest in STEM but this interest wanes significantly by the time they reach the age of 15-16 years.

The realization that we need to invite girls to STEM-related areas at an early age is not new. Since the 1970s, there has been growing national and international concern about the 'swing from science' since it was found that girls were gravitating towards social science programs rather than science in their later-school years and in higher education. Maccoby and Jacklin (1974) note that girls who were in science, were predominantly in the biological sciences rather than the physical sciences. Although we have long grappled with efforts to attract girls to science, Singer (2017) argues that it is now critical, given the increasing demand for STEM graduates and a 'leaky' STEM pipeline.

## Research on STEM and Girls

Millions of research dollars have been poured into identifying reasons for the gender gap in STEM. Kanny, Sax and Riggers-Piehl (2014) conducted a systematic literature review of empirical research investigating STEM and girls at the college level in the U.S. over a 40-year period (1970-2010). They studied a total of 324 publications and identified five "meta-narrative explanations" for the STEM gender gap. These were "individual background characteristics, structural barriers in K-12 education, psychological factors, values and preferences: family influences and expectations, and perceptions of STEM fields" (p.127). Among the five groups, the maximum increase in terms of volume of research and number of publications over the 40-year period, was in the area of K-12 structural barriers. The majority of studies in this group focused on the factors contributing to high school girls' interest in taking science and mathematics courses and exploring the classroom experiences that may have diminished their interest. This finding is significant in that it highlights that stimulating and sustaining girls' interest in STEM while in school is critical for urging them to STEM disciplines at the college level. Another large study by Microsoft in Europe noted "practical experience and hands-on exercises" and "real life applications" as two of the five major factors that drive girls' interest (*Microsoft Global Diversity and Inclusion Report*, 2016) during the ages of 13-17 years. Based on these findings from empirical research, we propose that STEM content which is *societally meaningful* (with a clear narrative), or *personally meaningful* (catering to their own biological changes), would stimulate and sustain the interest of girls in this age group of 13-17 years.

## The Integrated STEM Curriculum

The *integrated* STEM curriculum implemented in K-12 schools emphasizes interdisciplinary learning across the physical sciences, biological sciences, mathematic, computing and engineering. Singer (2017) writes, "The integration of the physical sciences, computer science, biology, engineering, science education and mathematics is viewed as foundational for a deeper understanding of biological systems" (p.1). This is done through the *project-based learning* (PBL) approach which is the main strategy used in teaching an integrated STEM program (Mustafa, Ismail, Tasir & Mohamad Said, 2016). This method encourages an openness to cross-disciplinary ways of thinking which have been shown to have positive impacts on both students' interest and achievement in STEM courses (Wang, Moore, Roehrig & Park, 2011). We believe that the integrated curriculum and the PBL approach in STEM education serve as an ideal

platform for utilizing recent trends in mobile technology and applying empirical research findings to attract girls to STEM at the middle and high school levels.

## Making STEM Societally Meaningful and Biologically Relevant

Lina Nilsson (2015) found clear evidence that providing a social context and a narrative to STEM content was particularly successful in drawing women to STEM programs in higher education. Female enrollment in mechanical, chemical and computer engineering soared when the content is made more socially meaningful or aimed at achieving societal good. She found this to be true both at the undergraduate and graduate levels – when the content offers opportunities for students to work on projects such as "developing solutions for low-income communities,…designing solutions for clean drinking water, inventing medical diagnostic equipment for neglected tropical diseases, enabling local manufacturing in poor and remote regions", it appealed to a significantly larger number of women. Thus, she opines that we can attract more women to STEM disciplines in higher education if curricula are reframed to make more explicit the social context of STEM and its central role in the work for societal welfare.

We believe that a similar outcome can be achieved at the middle and high school levels if we provide girls with opportunities in STEM education to engage with societally important issues with a meaningful narrative. A powerful example of engaging girls at this age is Greta Thunberg, a 16-year-old from Sweden, the founder of the Youth Strike for Climate Change movement who has been nominated for the Nobel Peace prize (https://www.theguardian.com/world/2019/mar/11/greta-thunberg-schoolgirl-climate-change-warrior-some-people-can-let-things-go-i-cant). When she was 15, she began a solitary strike standing outside the Swedish parliament, demanding swift action and prompt changes to climate policies. Her commitment to a social issue has been exemplary and serves as an inspiration to thousands of young people around the world who have joined her passionate call for action against climate change. We propose that STEM teaching in the middle and high schools that highlights its *societal* relevance and impact, will help increase and sustain girls' interest in STEM-related fields. Similarly, highlighting the *biological* relevance of STEM to girls' personal lives, such as in understanding their biological processes of menstruation and pregnancy will also assist in drawing girls to STEM disciplines.

## Mobile Learning and the Use of Mobile Apps

Studies show that mobile learning has transformed the traditional classroom to make it more interactive and interesting for the learner (Shen, Wang & Pan, 2008). The teaching-learning process no longer needs to be restricted to the classroom (time and place) but can occur naturally outside of the formal classroom (Huang, Lin & Cheng, 2010). Using the mobile phone which students use in their everyday lives, in teaching and learning enables them to connect directly with other learners on a more personal level (Ward, Finley, Keil & Clay, 2013) and this has been found to be highly motivating for learners (Hsu & Ching, 2013; Hwang & Wu, 2014; Schmitz, Klemke & Specht, 2012).

## Mobile Apps in STEM Teaching

The smartphone was introduced in 2007 and has become commonplace very quickly. Statistics from 2015 indicate that three out of four teenagers between 13 and 17 years of age in the U.S. had smartphones (https://www.statista.com/statistics/476050/usage-of-smartphone-teens-age-gender/) and this trend has continued to increase. We believe that the ubiquitous smartphone and the advances in mobile apps have the potential to make teaching and learning STEM an engaged, natural and personal experience. STEM content can be taught using appropriate mobile apps that show the centrality of STEM in dealing with practical issues. These mobile apps can facilitate STEM leaning within a social or biological context and give girls the critical hands-on experience needed to stimulate and nurture their interest.

### Socially Relevant Mobile Apps

In this age of global connectivity, we are almost constantly bombarded with a wide range of information on social problems of global importance. Some of these are directly related to topics in STEM, such as climate change and the resulting ecological imbalance because of marked shifts in environmental concentrations of carbon dioxide, carbon monoxide, ozone, water vapor, surface air temperature and sea-level. Among the natural factors responsible for climate change are continental drifts, volcanoes, ocean currents and the atmosphere's chemical composition, whereas extra-terrestrial factors that cause climate change include solar output, solar storms, earth-sun geometry and interstellar dust. In addition, the man-made contributors of climate change are greenhouse emissions and global warming. The current alarming rate of global warming is attributed to effects of the carbon cycle, carbon sources, carbon emissions and deforestation. Warming of the world is evident from increase in its humidity, temperature over oceans, sea surface temperature, sea level, temperature over land, ocean heat content and air temperature near the earth's surface (troposphere) along with a decrease in glaciers, snow cover and sea ice. Recent years like 2016 have seen billion-dollar climate disasters in the U.S. (Smith, 2017). Due to the complex ramifications of climate change, in the U.S. it is considered a serious threat to national security (Engelke and Chiu, 2016).

### Mobile App *Earth Now*

"Earth Now" is a free, global climate change mobile app developed by the National Aeronautics and Space Administration (NASA) that enables monitoring various environmental parameters via a real-time, three dimensional display of data obtained from multiple satellites (https://climate.nasa.gov/earth-apps/). This indicates global climate change in terms of variations in atmospheric carbon dioxide, carbon monoxide, ozone, water vapor, surface air temperature and sea-level. The app demonstrates color-coded vital signs of the earth on a vivid interface with detailed information regarding the earth conditions, as well as the satellites involved in their detection (Figure 1).

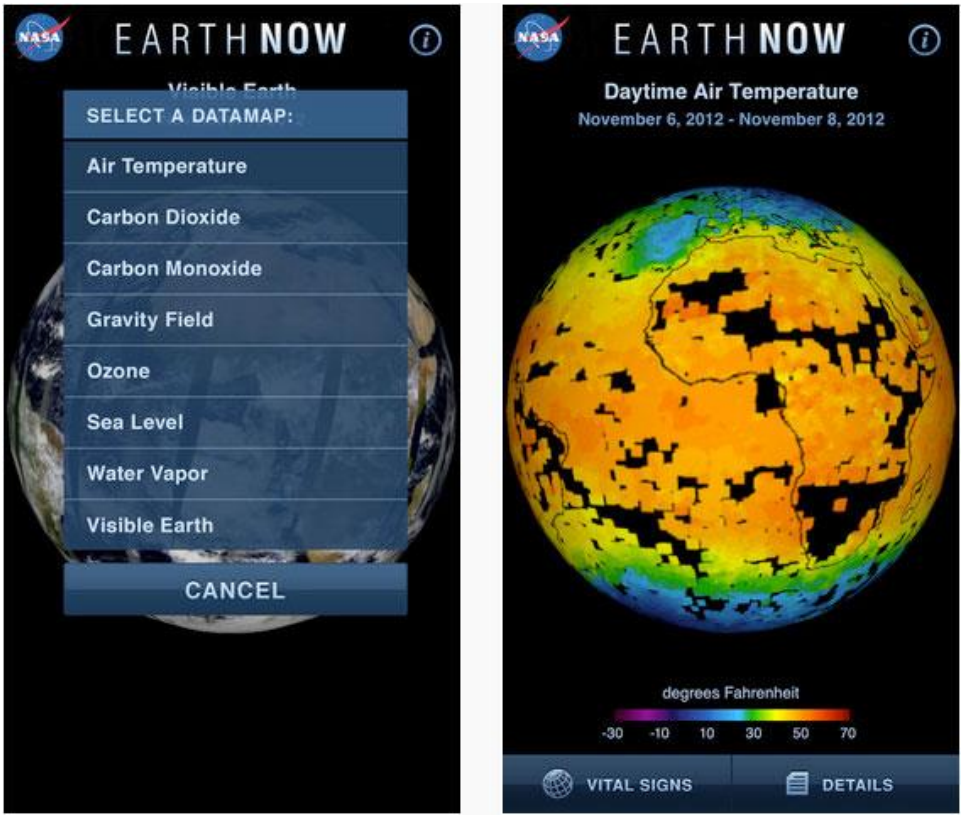


**Figure 1.** Navigation menu of *Earth Now*, a mobile app by NASA to detect global satellite data of various earth-conditions in real time. Razvanchy H., 2016 (https://www.yaleclimateconnections.org/2012/11/ten-great-climate-apps/).

**Mobile App *Offset***

*Offset* is another free mobile app designed by NASA (https://climatekids.nasa.gov/offset/) incorporating gamified activities. It is also available in a web version. Urquijo (2016) who reviewed this mobile app, explains that although originally designed for children, he finds that it effectively engages older players. Through an easy-to-use, fun interface (Figure 2), this mobile app teaches about the various causative agents of climate change such as greenhouse gases and fossil fuels as well as key approaches to counter these changes. It engages the player to design innovative ways to slow down climate change and global warming caused by the carbon cycle or carbon emissions by undertaking an array of varied methods including reforestation and alternative energy sources to counter the carbon sources.


**Figure 2.** Interface of the *Offset* mobile app – one of NASA's latest educational games to control climate change and global warming (https://www.greenappsandweb.com/en/ios-en/emit-co2-game/).

Mobile apps like *Earth Now* and *Offset*, if incorporated into teaching relevant topics in the STEM curriculum, would offer middle and high school girls an opportunity for personal, 'hands-on' experience with socially relevant, current issues like climate change and global warming. Spreading awareness through such exposure will hopefully lead them to develop or retain an interest in pursuing STEM fields.

**Biologically Relevant Mobile Apps**

With the onset of puberty, middle-to-high school aged girls start undergoing multifarious anatomical and physiological changes. Many of them face problems with the reproductive cycle such as amenorrhea (abnormal absence of menstruation in an un-pregnant condition), dysmenorrhea (painful menstruation/ menstrual cramps), irregular periods, pelvic inflammatory disease, ovarian cysts etc. which can potentially lead to infertility. On the other hand, unprotected sex or lack of contraceptives can result in sexually transmitted diseases and/or teenage pregnancy. Adolescent pregnancy can interrupt education and impose major socio-economic challenges on the girls, in addition to biological consequences such as, maternal mortality or health risks, premature birth and stillbirth. In the U.S., the rate of teen pregnancy is notably greater than in other western industrialized countries (Sedgh, Finer, Bankole, Eilers & Singh, 2015).

**Mobile App *Natural Cycles***

*Natural Cycles* is a "digital birth control" mobile app that indicates if a girl is fertile on a particular day, based on her body temperature in the morning and permits her to track her daily fertility status as shown in Figure 3 (McGoogan, 2017). For a woman with a

regular 28-day reproductive cycle, it can warn against intercourse on days when she is fertile and indicate other days when she can enjoy safe, unprotected sex without the possibility of getting pregnant. This is a hormone-free approach to contraception, needs no pill or device, and can be used to plan pregnancy. The app can help a girl understand the science of the menstrual cycle, reproduction and birth control. Girls can thus see the applicability of STEM in their own lives, being able to decide when they should use protection or abstain from sex and how to prevent unwanted pregnancies.


**Figure 3.** The *Natural Cycles* mobile app interface (top; https://www.naturalcycles.com/) showing how a woman can plan pregnancy by indicating the days of fertile versus non-fertile status based on her body temperature. It can also teach her the phases of menstrual cycle (bottom; http://blog.naturalcycles.com/tag/menstrual/).

**Mobile App *Girl Talk***

*Girl Talk* is a free mobile app that creates awareness among teenage girls about their reproductive anatomy, physiology, physical relationships and methods of protection from sexually transmitted infections or diseases. It provides comprehensive sexual health education to adolescent girls aged 12 to 17 years (Brayboy et al., 2017; https://www.boston-technology.com/case-study-girltalk/). It is easy to navigate and learn about sexual functions regulated by organs in the head (brain), breast (mammary glands) and abdomen (reproductive organs like ovary, uterus, vagina etc.) as shown on its simple interface (Figure 4).

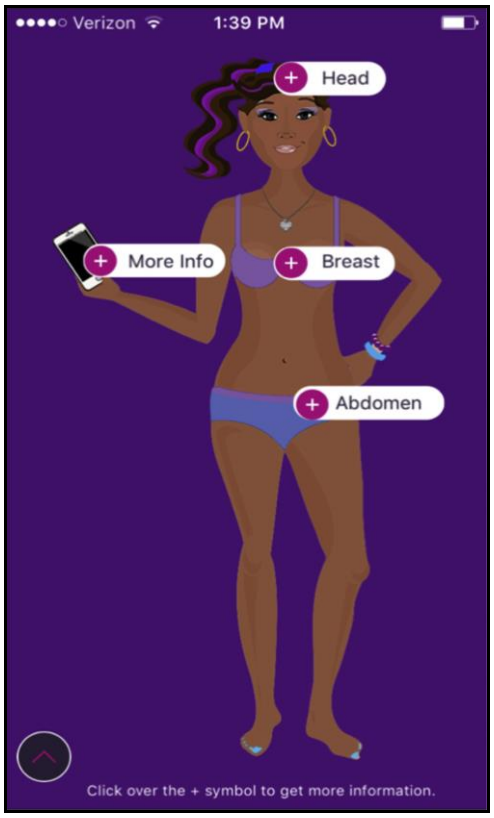


**Figure 4.** Navigation menu of the *Girl Talk* mobile app for sexual health education among girls (Brayboy et al., 2017).

Mobile apps like *Natural Cycles* and *Girl Talk* can be incorporated into pertinent topics in the STEM curriculum to offer middle and high school girls the opportunity to see the meaningfulness of STEM in their own lives and how it can play a vital role in enabling women to make informed personal choices.

## Significance and Future Directions

In this paper we proposed a research-based strategy to attract girls to STEM at an age when their interest appears to be waning, which is in their middle-to-high school years. We illustrate how the smartphone and four interactive, user-friendly, free or low-cost mobile applications, among others, can be harnessed into the formal teaching of relevant

topics of the STEM curriculum, providing a meaningful, hands-on experience for girls to engage with real-world societal problems or address their personal biological concerns. The dynamic accessibility and wide-range affordability of such mobile apps can also be leveraged to democratize out-of-school STEM activities for girls from even socio-economically challenged backgrounds. We believe such an opportunity for engagement during these formative years will develop, sustain, and enhance girls' interest in STEM education or careers. This would be instrumental in reducing the 'leakiness' of the STEM pipeline to college, while empowering young women to take informed decisions and be responsible global citizens. Further research at both middle and high school levels would enable collection of empirical evidence for the effectiveness of this strategy in attracting girls to STEM.

## Competing Interests

The authors have no competing interests.

## Authors' Contributions

Both the authors contributed equally to the paper, reviewing and combining all data to draft the manuscript. Both the authors prepared, read and approved the final manuscript.

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